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TRANSSACRAL PUNCTURE OF THE ARACHNOIDAL SAC

An alternative procedure to lumbar puncture

by

MATS HAVERLING

The method of puncturing the arachnoidal sac in the lumbar region was described by QUINKE in 1882 but was not commonly used before a second introduction by QUECKENSTEDT in 1916 (WILKINS 1965) The puncture is made between the spinal processes and the vertebral arches in the lower part of the lumbar region This technique has since become routine in obtaining fluid samples measuring fluid pressure and injecting air oxygen, isotopes and contrast media during examinations of the central nervous system as well as for including spinal anaesthesia

Lumbar puncture is usually easy to perform It may fail in patients with marked deformity of the spine caused by disk degeneration or scoliosis sub-occipital puncture of the cisterna magna and the transsacral approach may then be utilized

The sacral bone is illustrated in textbooks of anatomy (RAUBER & KOPSCH 1947 1968) as possessing a small opening on its dorsal aspect between the first and second vertebrae This is often reproduced in plastic skeletons (Fig 1) The foramen was however not encountered in an investigation of 22 human

From the Department of Neuroradiology (Director Prof T Greitz) Karolinska Sjukhuset Stockholm Sweden Submitted for publication 27 October 1970



Fig. 2 Transsacral puncture of the arachnoidal sac Marked scoliosis of the spine The tip of the needle penetrates the bony membrane at the dorsal aspect of spinal canal (arrow)

graphies All the subjects were adults the sexes being represented in equal numbers The punctures were made under local anaesthesia with 3 to 4 ml Citanest (Astra) injected into the soft tissues and the periosteum behind the upper part of the sacrum The puncture was made one to two centimeters caudally to the intervertebral disk between the fifth lumbar and the first sacral vertebrae the point being localized by palpation The puncture needle was directed slightly cranially and pushed through the bony membrane covering the sacral canal The first attempt at puncture was always made with a standard lumbar type of needle (1 0 mm OD) if this failed a second attempt was performed with a needle aimed at suboccipital puncture (1 4 mm OD)

Results

The bony membrane at the dorsal part of the sacral canal was penetrated by the needle in 8 of the 10 patients examined and the tip inserted into the arachnoidal sac in 5 of the patients Figs 2 and 3 represent an example of the

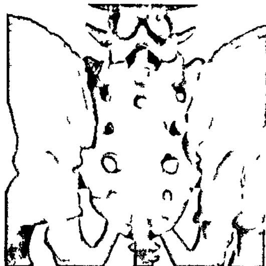


Fig 1 Sacral bone of an artificial skeleton with an opening in the facies dorsalis between the first and second vertebrae

sacral bones but the bony membrane in this region was observed to be thin and not more than 1 mm in thickness It therefore seemed possible to approach the arachnoidal sac by a transsacral route, a technique that in deformed spines may provide an alternative to lumbar puncture A further indication would be oxygen myelography because of the desirability to ensure as low a drainage as possible of the arachnoidal sac

The appearances of the caudal part of the spinal arachnoidal sac were investigated by ARNELL (1948) He established the variation in length of the arachnoidal sac as assessed in positive contrast myelograms and determined the relation of the sac to the sacral structures ARNELL examined 394 men and 177 women with normal appearance of the first sacral vertebra The shortest arachnoidal sac terminated at the level of the intervertebral disk between the fifth lumbar and the first sacral vertebrae The arachnoidal sac in 373 men and 168 women reached a point between the first and second sacral vertebrae, or slightly lower, and only exceptionally to the fourth sacral vertebra The terminal portion of the sac was cone shaped, the narrowing as a rule beginning at the level of the fifth lumbar and the first sacral vertebrae These investigations by ARNELL applied to the present problem suggested that it might be technically possible that in most patients the arachnoidal sac could be reached by transosseous puncture in the upper part of the sacrum of the thin bony membrane at the dorsal aspect of the sacral canal

Material and Method Attempts to puncture the arachnoidal sac by a transsacral procedure have been made in 10 patients to date One puncture was made in order to perform encephalography and the other nine for oxygen myelo

cisterna magna an examination that involves some risks and should be selected only by the experienced operator

The relationships between the arachnoidal sac and the lumbar and sacral spines were investigated by ARNELL and from a review of his work it was concluded that the sac could usually be reached by transsacral puncture In the present investigation puncture of the sac via the transsacral route was undertaken in 5 of the 10 patients One of these patients had marked deformity of the spine (Figs 2 and 3), i e severe scoliosis It was possible to puncture the arachnoidal sac in 4 of the remaining 9 patients, the sacral canal was punctured in 3 patients but the needle did not reach the sac which was probably too short or the puncture was made too low The bony membrane at the dorsal part of the sacral canal could not be perforated in the remaining 2 patients These were examined in the beginning of the series and no attempt was made to employ the larger suboccipital needle

Transsacral puncture, when possible for anatomic reasons is easily performed by the ordinary operator and should be attempted without delay in failure of lumbar puncture The risks are small and no vital tissue lies in the zone of puncture as against the conditions met with at suboccipital puncture No complications appeared following the eight punctures of the sacral canal in the present series A transsacral approach to the arachnoidal sac may therefore be recommended as an alternative

SUMMARY

Ordinary lumbar puncture of the arachnoidal sac may sometimes fail in patients with marked deformity of the spine Transsacral puncture at one to two centimeters below the L5—S1 joint may then constitute an alternative method Five out of 10 such punctures have been successfully utilized for encephalography and oxygen myelography

ZUSAMMENFASSUNG

Die gewohnliche Lumbalpunktion missgluckt ofters in Fallen von starker Deformitat der Lendenwirbelsaule Ein Ausweg in solchen Fallen ist dann die transsakrale Punktion ein bis zwei Zentimeter unterhalb des Niveaus L5—S1 In funf von zehn solchen Fallen ermoglichte dieses Vorgehen eine erfolgreiche Enzephalographie oder Oxygenmyelographie

RÉSUMÉ

La ponction lombaire habituelle de l etui arachnoidien peut echouer dans certains cas chez des sujets qui ont une deformation marquee de la colonne vertebrale La ponction trans acrée a un ou deux centimetres au dessous de l articulation L5—S1 peut alors constituer une methode de remplacement L auteur a utilisé avec succes dans cinq cas sur 10 une telle ponction pour l encephalographie et la myelographie à l oxygene



Fig 3 Encephalography (same patient as in fig 2) Stenosis of the posterior part of the Sylvian aqueduct (arrow) Obstruction to the circulation of fluid in the basal cistern

use of a transsacral puncture of the arachnoidal sac The patient, a middle aged woman, suffering from generalized Recklinghausen neurofibromatosis, had marked deformity of the thoracic and lumbar spines due to advanced scoliosis An attempt to perform lumbar puncture failed despite TV fluoroscopy On the following day an attempt to puncture the cisterna magna was made and was also unsuccessful as most of the air injected was deposited subdurally It was therefore decided to approach the arachnoidal sac via the transsacral route This was done (Fig 2) and encephalography (Fig 3) revealed stenosis of the posterior part of the Sylvian aqueduct and obstruction to the circulation of fluid in the basal cisterns Oxygen myelography following transsacral puncture was performed in an additional 4 patients

Discussion

The risks and rate of complications of puncture of the lumbar arachnoidal sac by the conventional technique are small The puncture in most patients is easily performed, but in a small group this method may be difficult or even impossible to carry out, e g in those patients with marked deformity of the lumbar spine These have been examined to date by suboccipital puncture of the

cisterna magna, an examination that involves some risks and should be selected only by the experienced operator

The relationships between the arachnoidal sac and the lumbar and sacral spines were investigated by ARNELL and from a review of his work it was concluded that the sac could usually be reached by transsacral puncture In the present investigation puncture of the sac via the transsacral route was undertaken in 5 of the 10 patients One of these patients had marked deformity of the spine (Figs 2 and 3) i e severe scoliosis It was possible to puncture the arachnoidal sac in 4 of the remaining 9 patients the sacral canal was punctured in 3 patients but the needle did not reach the sac which was probably too short or the puncture was made too low The bony membrane at the dorsal part of the sacral canal could not be perforated in the remaining 2 patients These were examined in the beginning of the series and no attempt was made to employ the larger suboccipital needle

Transsacral puncture when possible for anatomic reasons is easily performed by the ordinary operator and should be attempted without delay in failure of lumbar puncture The risks are small and no vital tissue lies in the zone of puncture as against the conditions met with at suboccipital puncture No complications appeared following the eight punctures of the sacral canal in the present series A transsacral approach to the arachnoidal sac may therefore be recommended as an alternative

SUMMARY

Ordinary lumbar puncture of the arachnoidal sac may sometimes fail in patients with marked deformity of the spine Transsacral puncture at one to two centimeters below the L5—S1 joint may then constitute an alternative method Five out of 10 such punctures have been successfully utilized for encephalography and oxygen myelography

ZUSAMMENFASSUNG

Die gewohnliche Lumbalpunktion missgluckt ofters in Fallen von starker Deformitat der Lendenwirbelsaule Ein Ausweg in solchen Fallen ist dann die transsakrale Punktion ein bis zwei Zentimeter unterhalb des Niveaus L5—S1 In funf von zehn solchen Fallen ermoglichte dieses Vorgehen eine erfolgreiche Enzephalographie oder Oxygenmyelographie

RÉSUMÉ

La ponction lombaire habituelle de l etui arachnoidien peut echouer dans certains cas chez des sujets qui ont une deformation marquee de la colonne vertebrale La ponction transsacree a un *ou deux* centimetres au des ous de l articulation L5—S1 peut alors constituer une method de remplacement L auteur a utilise avec succes dans cinq cas sur 10 une telle ponction pour l encephalographie et la myelographie a l oxygene

REFERENCES

ARNELL S Myelography with water soluble contrast Acta radiol (1948) Suppl No 75
RAUBER A und KOPSCH F Lehrbuch und Atlas der Anatomie des Menschen 17 Auflage Band I George Thieme Leipzig 1947
— Lehrbuch und Atlas der Anatomie des Menschen 20 Auflage, Band I Georg Thieme Stuttgart 1968
WESTBERG G Gas myelography and percutaneous puncture in the diagnosis of spinal cord cysts Acta radiol (1966) Suppl No 252
WILKINS R H Neurosurgical classics Johnson Reprint Corp New York 1965

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ANGIOGRAPHIC DOCUMENTATION OF THE DEVELOPMENT OF CEREBRAL CIRCULATORY ARREST

by

E BERGQUIST and K BERGSTROM

Angiography may be performed for absolute certainty and final verification when cerebral death (total cerebral infarction) has been diagnosed from clinical criteria (BUCHELER et coll BERGQUIST & BERGSTROM) Such a diagnosis is usually supported by an isoelectric EEG and perhaps an isotope examination The angiographic proof is that no contrast medium passes through the cerebral vessels This report illustrates the rapidity with which cerebral circulatory arrest may develop

Case report

Female aged 62 who had been treated for essential hypertension and auricular fibrillation eight years previously was admitted unconscious after collapsing at home She gradually improved but 24 hours later complained of severe headache No neck rigidity or paresis the Babinski sign was absent bilaterally

Right carotid angiography was performed about a week after admission The common carotid artery was punctured and the tip of a catheter placed at the bifurcation level the location being checked with contrast medium and films over the neck and base of the skull The internal carotid artery and carotid siphon filled well and the arterial branches close to the siphon were also outlined no other regions were included (Fig 1) Up till this

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Fig 1 Angiogram obtained during injection of contrast medium into the right internal carotid artery No obstruction of flow

moment the patient was conscious and able to speak but about 5 min later she suddenly had convulsions rapidly lost consciousness and stopped breathing Intubation was performed and artificial ventilation started

A further injection of contrast medium was given through the same catheter about 5 min after the change in the patient s condition Serial angiography revealed considerable delay in the flow with some sedimentation of the contrast medium in the internal carotid artery (Fig 2a) An irregular extravasal accumulation of contrast medium within an area of about 8 mm×6 mm in size at the level of the upper part of the carotid siphon close to the bifurcation suggested a ruptured aneurysm A further aneurysm about 3 mm in diameter lay in the pericallosal artery Marked vascular spasm of the pericallosal and calloso marginal arteries was evident and the arteries of the Sylvian group remained unfilled This part of the examination including inspection of the films took about 10 minutes

Four vessel angiography to obtain some idea of the entire cerebral circulation was then performed by percutaneous puncture of the right femoral artery and the advance of a grey Ödman catheter so that the tip lay in the ascending aorta About 30 min after the last in jection into the right internal carotid artery the first series of films was obtained In this as in two subsequent series stagnation of the contrast medium in both internal carotid arteries as well as in the vertebral arteries about 4 to 5 cm below the base of the skull was evident no medium passed upwards into the brain (Fig 2b) The external carotid artery

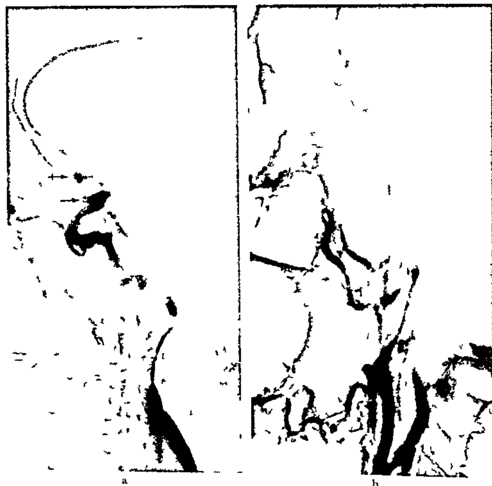


Fig 2 Subtraction films a) Angiogram 14 s after commencement of the second injection Extravasation of contrast medium at the carotid bifurcation indicates a ruptured aneurysm (→) a small aneurysm in the pericallosal artery is also evident (↔) Marked vascular spasm no filling of arteries of the Sylvian group b) Four vessel angiography performed about 30 min later No intracranial circulation but extracranial branches of the external carotid artery are filled

was well filled in the cervical region and the extracranial branches were also outlined On the other hand the meningeal arteries failed to fill The interval between the first injection when the patient was still conscious and the demonstration of cerebral circulatory arrest was about 45 minutes

The patient died 2 hours later Autopsy revealed a ruptured aneurysm of the right anterior cerebral artery close to the carotid siphon a collection of blood in the subarachnoid region and evidence that the intracranial pressure had been elevated (smoothness of the gyri and sulci pressure cones in the cerebellum and bilateral impressions in the uncal area)



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RÉSUMÉ

L'évolution des signes angiographiques caractéristiques de la mort cérébrale (ramollissement cérébral total) a été étudiée par des angiographies répétées chez un malade qui avait eu une rupture d'anévrisme intracranien au cours du premier examen. Les auteurs étudient les modifications probables qui conduisent à la phase finale.

REFERENCES

BERGQUIST E. and BERGSTROM K. Angiography in cerebral death. To be published in Acta radiol. Diagnosis.

BUCHELER E., KAUFER C. und DUX A. Zerebrale Angiographie zur Bestimmung des Hirntodes. Fortschr. Rontgenstr. 113 (1970) 278.

HEISKANEN O. Cerebral circulatory arrest caused by acute increase of intracranial pressure. A clinical and roentgenological study of 25 cases. Acta neurol. scand. (1964) Suppl. No. 7.

PONTÉN U. Intracraniell tryckstegring (In Swedish.) Opusc. med. (1970) Suppl. No. 11, p. 155.

Discussion

The cerebral circulation in this case thus deteriorated progressively and was finally arrested completely, all within the space of about 45 minutes. The first injection of contrast medium was given when the patient was still conscious and there was no evidence that the flow in the internal carotid artery was delayed; the patient then lost consciousness and stopped breathing. Further angiography indicated a ruptured aneurysm and spasm and that the circulation had almost stopped.

No patient in whom it has been possible to follow the development of cerebral death (total cerebral infarction) appears previously to have been described. Advanced necrosis of the brain was not evident at autopsy, however, since the patient died only 2 hours after the cerebral circulation had become arrested. It was thus possible in this patient to determine the length of the phase within which cerebral circulatory arrest may occur; in this instance it was just over 30 minutes. Clinical experience indicates, however, that the length of this phase may vary considerably. PONTÉN (1970) has stated that in cranial injuries and cerebral haemorrhage, for example, intracranial pressure measurements may reveal plateau waves characterized by a rapid pressure rise from slightly elevated or even normal basal values. A high pressure level may be reached (over 100 mm Hg) during the course of a few minutes and remain more or less unchanged for at least 5 minutes and sometimes considerably longer. This indicates that an intracranial pressure increase may occur rapidly and if, as pointed out by HEISKANEN (1963), spasm in the larger cerebral arteries is added, may constitute one more factor contributing to a pressure level high enough to result in arrest of the cerebral circulation. Since, however, the circulatory arrest develops within such a short time, it may be asked whether the spasm spreads and becomes so marked that severe vascular constriction gradually produces cessation of the blood flow.

SUMMARY

The development of angiographic appearances characteristic of cerebral death (total cerebral infarction) were documented by repeat angiographies in a patient in whom an intracranial aneurysm ruptured during the initial examination. The probable chain of events leading to the final phase are discussed.

ZUSAMMENFASSUNG

Die Entwicklung des für den zerebralen Tod (totale zerebrale Infarcierung) charakteristischen angiographischen Bildes wird durch wiederholte Angiographien bei einem Patienten nachgewiesen, bei dem eine Ruptur des intrakraniellen Aneurysmas bei der initialen Untersuchung entstand. Der wahrscheinliche Ablauf der Ereignisse, die zur Schlussphase führten, wird besprochen.

Table 1

The toxicity of the contrast media compared to iodomethane Na sulfonate LD_{50} by intracerebral route in mice given in mg I/kg

Contrast medium	mg I/kg
Diatrizoate meglumine (Hypaque)	40
Iodomethane Na sulfonate (Kontrast U)	112
Iothalamate meglumine (Conray Meglumin)	150
Dimer iothalamate (Dimer X)	290

that the examination may be regarded as being relatively safe, if diatzepam is used either in premedication or in treating tendencies to cramp or spasm The e latter may occur after the examination as signs of irritation and on which diatzepam has a specific action (CARUSELLI & SALVOLINI 1967)

The toxicity of the contrast medium was proved to have decreased upon the introduction of iothalamate acid dimer (GONSETTE & ANDRE BALISAUX 1970) (Table 1) It was therefore expected that the side effects would be further reduced in lumbar myelography if dimer contrast medium was used

The roentgenographic technique that the present authors employ in lumbar myelography *without anaesthesia* differs essentially from the one commonly used The films are obtained with the patient lying as well as standing and bending and thus depicting function Changes in the degree of a prolapsed disk may also be investigated by means of the Lasegue test during the examination It was assumed that the side effects would be greater with this technique and it was therefore considered that those produced during myelography with Conray Meglumin and Dimer X should be compared

Material and Methods The comparison covered roughly the first 50 Conray and the first 50 Dimer X myelographies The roentgen method (KORHONEN et coll) allows observation even of small changes but because of the extent of the exercises may increase the side effects

The same premedication method was used in both series diatzepam 5 to 15 mg + pethidin 50 to 75 mg both intramuscularly one hour before the examination The patients were then given 10 mg diatzepam × 3 per os for 48 hours and after the examination spent the rest of the day in the reversed Trendelenburg position

Comparison of side effects The side effects may be divided into three groups meningeal irritation which usually occurs later radicular signs which appear immediately and hyperexcitation signs which arise always later Meningeal

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SIDE EFFECTS OF CONRAY MEGLUMIN 282 AND DIMER-X IN LUMBAR MYELOGRAPHY

by

E. LEHTINEN and S. SEPPANEN

Attempts were made during the last decade to replace the myelography contrast media then in use with water soluble substances not necessitating spinal anaesthesia. Experiments were made with the Schering biloptin acid suspension (*SH 617 L*). ZEITLER (*1965, 1968*) reported considerable side effects from this contrast medium although these were not confirmed by WIDOK & SCHMERWITZ (1968) who recommended its adoption. A more detailed review of the literature has been given by LINDGREN & TORNELL (1969) who also described severe leptomeningeal reactions in experiments with SH 617 L in dogs. The use of biloptin acid has now been generally abandoned.

CAMPBELL et coll. (1964) published twelve myelograms obtained with Conray Meglumin. They stated, however, that the side effects were too great to allow of the general use of this medium. Numerous publications have since appeared concerning the possibilities of employing Conray Meglumin in myelography, e.g. GONSETTE & ANDRE-BALISAUX (1968), BAUMGARTNER et coll. (1968), DAVIS et coll. (1968), AHLGREN (1969) and PRAESTHOLM & LESTER (1970). It has become evident that side effects may be greatly reduced, even to such an extent

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This author mentioned that the administration of diatzepam constituted a good prophylatic measure he did not include diatzepam however, in the premedication

Signs of meningeal irritation mostly headache appeared in 12 per cent o' patients in the material of 847 Conray myelographies gathered by GONETTE (1971) Radicular signs occurred in 5 per cent and hyperexcitation in 4 per cent of patients In the Dimer material (630 patients) of the same inve tigation meningeal signs were ob erved in 22 per cent radicular igns in 2 per cent and hyperexcitation in 1 per cent of patients Diatzepam was not u ed in the premedication but diatzepam was given to eliminate any side effects that appeared

A comparison of the percentages of the present authors of the ide effects with the e latter figures it is evident that their technique in which a greater likelihood of the contrast medium rising in the spinal canal to the level of the medulla exists produces a significant increa e in the number of side effects This was not improved even by diatzepam premedication The amount of meningeal irritation in the Dimer myelographies was however, much smaller than in those patients in whom premedication was not applied Comparisons of myelographies performed with the identical technique the two different contrast media and identical medication indicate that the degree of the side effects was always substantially and significantly less in the Dimer myelographies

Conclusion

The u e of iothalamate contrast media in lumbar myelographies is expedient because their higher iodine content will naturally produce end results superior to those attained with iodomethan The ab ence of spinal anaesthesia ensures that the patients will be cooperative throughout the examination and precludes complications inherent in such a procedure Complications occurred in 32 per cent of the patients and the symptoms and signs were evenly distributed over all the categories of side effects No substantial difference in frequency of the side effects was evident in a comparison with a material in which diatzepam was withheld The relative number of sequelae in the Dimer myelographies declined however to 11 per cent and the side effects were extremely slight

SUMMARY

A omparison of 50 myelographies performed with Dimer X and 50 similar examinations with Conray indicates the advantage and better end results obtained with the former The merit of the absence of spinal anaesthesia is emphasized

Table 2

The frequency and types of the side effects with both contrast media

	Conray Meglumin 282	Dimer X
Number of myelographies	56	54
Number of patients with side effects	18 (32 %)	6 (11 %)
Meningeal irritation	9 (17 %)	3 (5 5 %)
Cephalalgia	9	2
Nausea	0	1
Rise in temperature	0	0
Radicular signs	12 (21 5 %)	2 (3 5 %)
Sensations	9	1
Hyperalgesia	3	1
Cauda equina syndrome	0	0
Hyperexcitation signs	8 (14 %)	3 (5 5 %)
Muscle rigidity	5	1
Myoclonia	3	2
Epileptic fits	0	0
Death	0	0

irritation includes headache, nausea, vomiting and a rise in temperature Radi-
cular symptoms and signs consist of various sensations, hyperaesthesia an
possibly the cauda equina syndrome, the signs of hyperexcitation includ
muscular rigidities and contractions, myoclonia, and epileptic fits, to terminat
in death

Side effects appeared in 32 per cent of the patients in the Conray series and i
11 per cent of those in the Dimer series (Table 2) Seventeen per cent of th
effects in the former consisted of headache and immediate vague pain and 1
per cent of hyperexcitation Diazepam intravenously administered alway
alleviated or eliminated cramp Eleven per cent of the Dimer material presente
evidence of complications Only 5 5 per cent of the patients had headache o
nausea, while 5 5 per cent had muscular cramp

Discussion

Immediate side effects in Conray myelography appeared in *105/125*, i e
in 84 per cent of the patients of the material of AHLGREN Delayed complication
included chronic spasm in 8/125 and a rise in temperature in 21/125 patients

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ADHESIVE ARACHNOIDITIS AFTER LUMBAR MYELOGRAPHY WITH MEGLUMINE IOTHALAMATE (CONRAY)

by

EINO AUTIO JORMA SUOLANEN SET NORRBACK and PÄR SLÄTIS

The requirements of an ideal myelographic contrast medium — good miscibility with the cerebrospinal fluid complete absorption sufficient contrast producing characteristics no toxicity and inert pharmacologic properties (FISHER 1965 SHAPIRO 1968 AHLGREN 1969) — are not as yet fulfilled by any contrast medium available In oluble iophendylate (Pantopaque), still u ed in many centres is associated with significant disadvantages (DI CHIRO & FISHER 1964, whereas the properties of water soluble monoiodomethane sulfonate (Conturex Kontrast U) necessitate spinal anae thesia before its intrathecal injection Gas is of limited value in the diagnosis of lumbo acral root compressions and serious criticism has been levelled at the new contrast medium SH 617 L intended for myelography due to well documented leptomeningeal reactions following its use (LINDGREN & TORNELL 1969)

CAMPBELL et coll (1964) reported their first experiences with water oluble iothalamate (Conray) as a myelographic contrast medium Accumulating reports revealed a substance of seemingly low toxicity adequate contrast producing properties and complete ab orption (GONSETTE & ANDRE BALISAUX 1968 BAUMGARTNER et coll 1968 DAVIS et coll 1968 AHLGREN 1969 PRAEST

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ZUSAMMENFASSUNG

Ein Vergleich von 50 Myelographien ausgeführt mit Dimer X und 50 ähnliche Untersuchungen mit Conray lassen die Vorteile und besseren Endresultate bei Anwendung von Dimer X erkennen Der Vorteil der Abwesenheit einer Spinalanästhesie wird hervorgehoben

RÉSUMÉ

Les auteurs ont comparé les résultats de 50 myélographies faites avec le Dimer X et de 50 examens analogues faits avec le Conray cette comparaison montre l avantage et le meilleur résultat final obtenu avec le Dimer X Les auteurs soulignent l intérêt de l absence d anesthésie rachidienne

REFERENCES

AHLGREN P Lumbale Myelographie mit Conray Meglumin 282 Fortschr Röntgenstr 111 (1969) 270

BAUMGARTNER J BRAUN J P RUST I et coll Amélioration de la technique de l examen radiculosaccographique par utilisation d un nouveau produit de contraste Neuro Chirurgie 14 (1968) 909

CAMPBELL R L CAMPBELL J A HEIMBURGER R F et coll Ventriculography and myelography with absorbable radiopaque medium Radiology 82 (1964) 286

CARUSELLI G e SALVOLINI U Il metildiazepione come premedicazione negli esami neuroradiologici (In Italian) Acta anesth 18 (1967) 377

DAVIS F M LLEWELLYN R C and KIRGIS H D Water soluble contrast myelography using meglumine iothalamate (Conray) with methylprednisolone acetate (Depo Medrol) Radiology 90 (1968) 705

GONSETTE R An experimental and clinical assessment of water soluble contrast medium in neuroradiology A new medium — Dimer X Clin Radiol 22 (1971) 44

— et ANDRE BALISAUX G Nouvelle technique de radiculographie lombo sacrée par produit hydrosoluble résorbable sans rachianesthésie Ann Radiol 11 (1968) 141

KORHONEN M LEHTINEN E and SEPPANEN S Functional lumbar myelography with meglumin iothalamate and dimer iothalamate To be published in Ann clin Res

LINDGREN E and TORNELL G Experiences with SH 617 L Acta radiol Diagnosis 9 (1969) 701

PRAESTHOLM J and LESTER J *Water soluble contrast lumbar myelography with meglumine* iothalamate (Conray) Brit J Radiol 43 (1970) 303

WIDOK W und SCHMERWITZ W Myelographie mit einer resorbierbaren Suspension Fortschr Röntgenstr 108 (1968) 151

ZEITLER E Suspensions Myelographie und Funktionsdiagnostik der Lendenwirbelsäule Fortschr Med 86 (1968) 587

— und DIETZ H *Über den diagnostischen Wert der Myelographie mit Suspensionen* Radiologe 5 (1965) 489



Fig 2 Case 2 a) First Conray myelography frontal view Excellent filling of root sleeves b) Second Conray *myelography 3 months* later Signs of adhesive arachnoiditis narrowing of the dural sac and amputated appearance of all root sleeves

Fig 3 Case 3 a) First Conray myelography left oblique view Good filling of root sleeves b) Same projection at repeat myelography the S1 root sleeve is rounded and the distal sacral root pouches remain unfilled

The control series consisted of another 12 patients previously examined with monoiodomethane sulfonate (Kontrast U) as contrast medium and subsequently submitted for repeat myelography with meglumine iothalamate

Myelographic technique The procedure closely corresponded to that described by AHLGREN (1969), and was always followed uniformly *in all* patients Lumbar puncture with a 1 0 mm gauge needle was carried out with the patient lying on his side on a roentgen table tilted head-end up *from about 10 to 40* degrees An amount of 7 ml Conray Meglumin 282 was *carefully diluted* with 3 ml of aspirated cerebrospinal fluid and after the injection of 3 ml of the mixture its spread was followed with a TV *image* intensifier Free distribution in the subarachnoidal space was followed by the slow injection of the remainder and lateral films were taken If *no* adverse side effects occurred the needle was withdrawn and appropriate films obtained in the prone and oblique positions

The contrast medium was not aspirated, test films revealed that the last traces disappeared within 6 to 8 hours The patient was directed to remain in a semi recumbent position for at least 6 hours after completion of the examination



Fig. 1. Case 1. First Conray myelography. a) and b) Delineation of the distal lumbar and sacral nerves and filling of the root sleeves. c) and d) Second Conray myelography 6 months later. Compared with the previous myelography, the sacral root sleeves remain unfilled, the right L5 root pouch is blunted and the left L5 root pouch is poorly outlined. Both L4 root sleeves end abruptly.

holm & Lester 1970, Edgren & Tallroth 1970, Ilstam et coll. 1970). However, adverse side effects were regularly reported — most commonly characterized by transitory involuntary muscular tic movements, pain and rigidity of the lower limbs. Campbell et coll. (1964) and Fisher (1965) failed to observe histologic evidence of toxic effects after the intrathecal injection of iothalamate in animals; no persistent late pathologic changes have been reported in clinical practice.

This investigation was initiated by the observation of signs of adhesive arachnoiditis in a patient twice subjected to myelography with meglumine iothalamate. Perusal of the entire myelography series revealed that adhesions were common at repeat myelography.

The series comprises 101 myelographies in patients admitted with sciatic pain or signs of lumbosacral root compression during the period October 1969 to February 1971. Six of these patients had twice been subjected to myelography with meglumine iothalamate and the radiographic and clinical follow up data will be reported.



Fig 2 Case 3 a) First Conray myelography frontal view Excellent filling of root sleeves b) Second Conray myelography 3 months later Signs of adhesive arachnoiditis narrowing of the dural sac and amputated appearance of all root sleeves



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Fig. 4. Case 4. a) First Conray myelography, left oblique view. Good filling of root sleeves. b) Same projection at re-examination five months later. All sacral and the L5 root sleeves end abruptly and remain poorly delineated. The delicate striated appearance of the cauda equina observed in the first myelography has disappeared.

Fig. 5. Case 5. a) First examination, frontal view. Small cystic dilatations of the sacral root pouches. b) At re-examination the cystic dilatations as well as the sacral and L5 root sleeves remain unfilled.

Case reports

Case 1. Man, aged 31, with intermittent signs and symptoms of compression of the right S1 root. Myelography with Conray failed to reveal obvious changes and the patient was given conservative treatment. Persistent radicular signs suggested a second Conray myelography 6 months later (Fig. 1). The sacral root sleeves now did not fill and the right L5 root sleeve and both L4 root sleeves were poorly delineated. The cause of these signs was not apparent. The clinical follow-up revealed normal mobility of the lumbar spine and no neurologic changes. The patient had no symptoms and had returned to his previous industrial work.

Case 2. Woman, aged 27, with signs of compression of the right S1 root. This was verified at the first myelographic examination but operation was deferred owing to remission of the symptoms. A further severe attack of sciatic pain prompted a second myelography three months later; this demonstrated a disk protrusion at the L5—S1 level that was confirmed at operation. Comparison of the roentgenograms from the two examinations (Fig. 2) revealed that in the later the sacral root pouches remained unfilled with contrast medium



a b

Fig 6 Case 6 First Conray myelography frontal view b) Second Conray myelography blunt appearances of short sacral root sleeves The dural sac is narrowed

the L5 root sleeves had blunted ends and the dural sac was constricted Control Full recovery adequate mobility of the lumbar spine and absence of sciatic pain No lumbosacral root damage was evident

Case 3 Man aged 29 with right sided sciatic pain with vague clinical signs of L5 root involvement Myelography normal (Fig 3) Owing to unsatisfactory recovery and persistent working disability myelography was repeated 6 months later no sign of disk protrusion was apparent but the sacral root pouches were now poorly or totally unfilled with contrast medium Normal neurologic findings but aching pain on strenuous effort was recorded at the clinical control

Case 4 Man aged 37 with intermittent left sided sciatic pain with clinical signs of S1 root involvement Myelography revealed normal conditions (Fig 4) and the conservative therapeutic regime was continued Owing to continuous symptoms and persistent signs further myelography was performed 5 months later No disk protrusion was evident but neither the L5 root pair nor the sacral root sleeves could be outlined and the L4 roots had blunted ends and an amputated appearance The dural sac seemed to be constricted The follow up examination indicated complete recovery with no symptoms and normal neurologic signs

The primary myelography had been performed in another hospital by a similar radiographic technique with Conray as contrast medium in 2 further patients

Case 5 Man aged 41 with long-standing signs and symptoms of compression of the right L5 root Myelography revealed small cystic dilatations of the sacral nerve pouches but *no*

evidence of root compression Repeat myelography 2 months later presented altered radiographic appearances there were still no signs of root compression but the cysts and the lower sacral root pouches remained unfilled (Fig 5) Clinical control Diminishing sciatic pain but impaired working ability Remission of the neurologic signs

Case 6 Woman aged 35, with intermittent right sided sciatic pain with signs of L5 root involvement Myelography was normal (Fig 6) but the examination was repeated 3 months later because of disabling radiating low back pain No root compression was evident but in comparison with previous findings the sacral root sleeves had disappeared The L5 root pair seemed normal The follow up note recorded that the patient had returned to work but still suffered from low back pain No functional defect was evident in the neurologic examination

A high frequency of complications occurred shortly after the second procedure Three out of 6 patients suffered from involuntary tic movements or shooting pain in the buttocks or lower limbs lasting from 2 to 6 hours

Comments on the radiographic findings All six patients who had been subjected to a repeat myelographic examination with meglumine iothalamate, had signs in the second examination pointing to arachnoiditis, characterized by adhesions in the root sleeves, and constriction of the dural sac The changes were uniform the lower sacral root sleeves were most affected and obtruded, whereas the reactive changes diminished cephalad Thus, the root pouches of the sacral roots were always affected, those of the L5 roots in 4 patients and those of the L4 roots in 2 patients The excellent roentgen appearances of the cauda equina obtained in the first myelography were never repeated at a second examination the appearances resembled Pantopaque myelographies with blunted contours and amputated appearances of the root sleeves

The time interval between the first and second examinations varied from 2 to 6 months No correlation between the time interval, on the one hand, and the seriousness of the adhesive arachnoiditis, on the other, could be established although the series is too small to warrant any definite conclusions In none of the 12 patients in whom myelography had previously been performed with monoiodomethane sulfonate (Kontrast U), did a re examination with meglumine iothalamate (Conray) reveal any signs of arachnoiditis all root sleeves remained clearly delineated and the dural sac unaffected

Discussion

Experimental investigations by CAMPBELL et coll (1964) and FISHER (1965) failed to reveal histologic evidence of leptomeningeal reactions up to 3 months after the intrathecal injection of Conray Five minutes after the instillation of ^{131}I sodium iothalamate into the cisterna magna CAMPBELL et coll (1964) and

HEIMBURGER et coll (1965) observed radio activity in the blood reaching peak values at 45 and 75 minutes after the injection Almost 100 per cent of the substance was recovered from the urine within 24 hours FISHER (1965), however, from the reactions observed in cats during injections of Conray presumed, that the substance might be extremely irritating in spite of the negative histologic findings DAVIS et coll (1968) recently suggested the addition of methylprednisolone to the contrast medium to minimize the risk of arachnoiditis Positive evidence of the benefit of such a procedure is still lacking

The amount of contrast medium was the same and produced recognizable contrast at the L1 and L2 levels in all the patients examined The major part of the hyperbaric substance gradually accumulated in the lowermost part of the dural sac thus giving rise to a high concentration around the neural element and ensheathing structures Radiographic evidence of adhesive arachnoiditis was common in the most caudad root sleeves but less marked in the upper root pairs It is reasonable to assume that an aseptic arachnoidal reaction is responsible for the radiographic changes which alter according to the concentration of the contrast medium at any given level The substantial drawback in the use of meglumine iothalamate apart from the possible late sequelae of arachnoiditis is the blurring effect on any subsequent myelography rendering adequate diagnosis difficult or impossible Clinical control examination of the patients failed to reveal any objective sign of persistent lumbosacral root damage

A comprehensive report on the follow up results of all patients in the series subjected to myelography with meglumine iothalamate and the results of the histologic examination of the biopsies of the meninges will be published in a further paper

SUMMARY

Six of 101 patients with signs of compression of the lumbosacral roots who had been subjected to myelography were examined again with meglumine iothalamate (Conray Meglumin 282) and all found to have evidence of adhesive arachnoiditis It would appear that this contrast medium produces a leptomeningeal reaction severe enough to interfere seriously with the diagnostic value of any subsequent myelography

ZUSAMMENFASSUNG

Sechs von 101 Patienten mit Zeichen einer Kompression der lumbosacralen Wurzeln die einer Myelographie unterzogen worden waren wurden erneut mit Meglumine Iothalamate (Conray Meglumin 282) untersucht wobei alle Patienten Zeichen einer adhäsiven Arachnoiditis aufwiesen Es scheint so als ob dieses Kontrastmittel eine leptomeningeale Reaktion hervorruft die schwer genug ist um wesentlich den diagnostischen Wert irgendeiner nachfolgenden Myelographie herabzusetzen.

evidence of root compression Repeat myelography 2 months later presented altered radiographic appearances there were still no signs of root compression but the cysts and the lower sacral root pouches remained unfilled (Fig. 5) Clinical control Diminishing sciatic pain but impaired working ability Remission of the neurologic signs

Case 6 Woman, aged 35 with intermittent right sided sciatic pain with signs of L5 root involvement Myelography was normal (Fig. 6) but the examination was repeated 3 months later because of disabling radiating low back pain No root compression was evident but in comparison with previous findings the sacral root sleeves had disappeared The L5 root pair seemed normal The follow up note recorded that the patient had returned to work but still suffered from low back pain No functional defect was evident in the neurologic examination

A high frequency of complications occurred shortly after the second procedure Three out of 6 patients suffered from involuntary tic movements or shooting pain in the buttocks or lower limbs lasting from 2 to 6 hours

Comments on the radiographic findings All six patients who had been subjected to a repeat myelographic examination with meglumine iothalamate, had signs in the second examination pointing to arachnoiditis, characterized by adhesions in the root sleeves, and constriction of the dural sac The changes were uniform the lower sacral root sleeves were most affected and obtruded, whereas the reactive changes diminished cephalad Thus, the root pouches of the sacral roots were always affected, those of the L5 roots in 4 patients and those of the L4 roots in 2 patients The excellent roentgen appearances of the cauda equina obtained in the first myelography were never repeated at a second examination the appearances resembled Pantopaque myelographies with blunted contours and amputated appearances of the root sleeves

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF H LODIN), AKADEMISKA SJUKHUSET UNIVERSITY OF UPPSALA, SWEDEN

CINERADIOGRAPHIC INVESTIGATIONS OF CONTRACTION IN THE NORMAL UPPER URINARY TRACT IN MAN

by

LARS BJORK and OLLE NYLEN

Only relatively few investigations of the normal upper urinary tract in man with urography and cineradiography have been performed This is in part explained by the difficulty in obtaining possibilities of carrying out such examinations in patients without any suggestion of disease of the urinary tract The results of earlier work are somewhat conflicting (CATEL & GARSCHE 1957 DUX et coll 1962 BELKER & POLLACK 1965) A diagnosis based upon the contractions that occur demands thorough appreciation of the normal conditions The appearances determined by cineradiography in a group of patients with no symptoms or signs of disease of the urinary tract are now presented

Material This consisted of 23 patients 14 males and 9 females referred for cardiac disease and examined with cardiac catheterization and cardioangiography The mean age of the men was 49 (range 28 to 63) and the women 40 years (range 23 to 59 years) only 2 of the women were under 40 years of age None of the patients had a history or symptoms of urinary tract disease The routine urinary analysis was normal in all patients There was no selection but patients who had vaso-vagal reactions during the catheterization procedure with a fall in blood pressure were not included The arterial blood pressure

Submitted for publication 23 December 1970

RÉSUMÉ

Sur 101 malades présentant des signes de compression des racines lombosacrées qui avaient subi une radiculographie par l'iothalamate de méglumine (Conray Meglumin 282) six ont été réexaminés avec le même moyen de contraste et avaient tous des signes d'arachnoïdite adhésive. Il semblerait que ce moyen de contraste produise une réaction leptoméningée assez sévère pour gêner sérieusement la valeur diagnostique de toute radiculographie ultérieure.

REFERENCES

AHLGREN P. Lumbale Myelographie mit Conray Meglumin 282. Fortschr. Röntgenstr. 111 (1969) 270.

BAUMGARTNER J., BRAUN J. P., RUST F. et coll. Amélioration de la technique de l'examen radiculosaccographique par utilisation d'un nouveau produit de contraste. Neuro-Chirurgie 14 (1968), 909.

CAMPBELL R. L., CAMPBELL J. A., HEIMBURGER R. F. et coll. Ventriculography and myelography with absorbable radiopaque medium. Radiology 82 (1964), 286.

DAVIS L. M., LLEWELLYN R. C. and KIRGIS H. D. Watersoluble contrast myelography using meglumine iothalamate (Conray) with methyl prednisole acetate (Depo-Medrol). Radiology 90 (1968), 705.

DI CHIRO G. and FISHER R. L. Contrast radiography of the spinal cord. Arch. Neurol. 11 (1964) 125.

EDGREN W. och TALLROTH K. Lumbal myelografi med jodtalaminmeglumin. (In Swedish.) Nord. Med. 83 (1970), 564.

FISHER R. L. An experimental evaluation of Pantopaque and other recently developed myelographic contrast media. Radiology 85 (1965), 537.

GONSETTE R. et ANDRÉ-BALISAUX G. Nouvelle technique de radiculographie lombo-sacrée par produit hydrosoluble résorbable sans rachianesthésie. Ann. Radiol. 11 (1968) 141.

HEIMBURGER R. F., KALSBECK J. E., CAMPBELL R. L. and MEALEY JR J. *Positive contrast* cerebral ventriculography using water soluble media. J. Neurol. Neurosurg. Psychiat. 29 (1966) 281.

IRSTAM L., SUNDSTRÖM R., LÖNNERHOLM T. och ZSIGMOND M. Lumbal myelografi med Conray Meglumin 282. (In Swedish.) Läk. Tidn. 67 (1970) 3185.

LINDGREN E. and TORNELL G. Experiences with SH 617 L. Acta radiol. Diagnosis 9 (1969) 701.

PRAESTHOLM J. and LESTER J. Water soluble contrast lumbar myelography with meglumine iothalamate (Conray). Brit. J. Radiol. 43 (1970) 303.

SHAPIRO R. Myelography. 2th edition p. 14. Year book medical publishers. Chicago 1968.

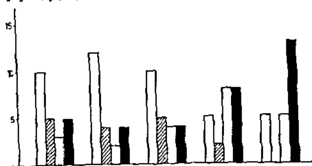


Fig 1 Degree of contractions in various parts of the normal upper urinary tract in 23 patients From left to right Upper middle and lower calyces and ampullar and ureteral pelvis ☐ No contraction ▨ < 50 % contractions ☐ > 50 % contractions ■ total contractions

Only one side of the upper urinary tracts was selected for cineradiographic investigation in each patient the selection being influenced only by bowel masking the right kidney was examined in 10 and the left kidney in 13 patients The cinefilms were analysed frame by frame in an Arno 35 mm cine projector The types of renal pelvis were classed as ampullar, bifid and ordinary The number of contractions in the upper urinary tract were recorded the starting point and degree of contraction of the various parts of the upper urinary tract were also noted

Results

The starting point of the contractions in 23 normal subjects is given below

Ureter	8
Ureter and ampullar pelvis simultaneously	6
Ampullar pelvis	3
Upper calyces	1
Lower calyces	1
All calyces simultaneously	1
Starting point undetermined	1
No contractions	2

They usually commenced in the upper part of ureter or in the ampullar pelvis and spread to other parts of the upper urinary tract it started in the calyces in only 3 patients

The degree of the contractions were divided into four groups 3 = total or nearly total contraction 2 = more than 50 per cent contraction 1 = less than 50 per cent contraction 0 = no contraction (Fig 1) The mean degree of

was usually within the normal range, 6 patients however had a diastolic blood pressure of between 100 and 105 mg Hg. None of the patients received any drug that could influence the contractions of the urinary tract and none had signs of decompensation, 6 patients were on long term treatment with diuretics.

Methods. The patients were subjected to cardiac catheterization and cardio-angiography as part of a routine evaluation of cardiac disease after premedication with 0.1 g penthymal and 0.25 mg lergigan, they received no solids or fluids six hours before the examination. Saline was administered during the examination to flush catheters, the amount depending on the length of the catheterization procedure, although it was fairly constant. The total amount of saline never exceeded 300 ml administered slowly over a period of 1 to 3 hours. All patients received a relatively large amount of contrast medium (Isopaque 350, sodium metrizoate with a small amount of calcium metrizoate added, iodine content 350 mg per ml, Nyegaard & Co, Oslo) for the cardio-angiographies. The average dose was 1.84 ml/kg body weight (range 0.7 to 2.4 ml/kg) given in 1 to 4 separate injections, with more than one injection the time interval between them was 10 to 15 minutes.

The cineradiographic investigations of the upper urinary tract were started 10 to 15 minutes after the last injection for the cardioangiography. A 9 inch image intensifier with a 35 mm cinecamera (Arriflex) operated at 20 or 30 frames per second produced pulsed cineradiographs with an exposure time of 0.003 second, exposure factors 320 mA and 55 to 75 kV. The rotating anode tube was of the high load type with a 0.6 mm × 0.6 mm focal spot. The length of the cine recordings was 3 minutes.

The radiation dose to the skin was measured in three female patients of various body weights. Thermoluminescent dosimeters were placed on the skin on the dorsum and in front in the centre of the field of radiation. In addition dosimeters were sited on the skin on the dorsum and front over the estimated position of the ovary on the same side. The skin dose to the dorsum was 230, 355 and 720 mrad/min in the centre of the field of radiation and in front 47, 52 and 140 mrad/min, respectively. The dorsal skin dose over the ovary was 10, 16 and 57 mrad/min and in the front was 10, 10 and 41 mrad/min, respectively. The geometric magnification technique with an enlargement factor of 1.5 to 1.8 was generally applied. The area examined was limited to a size of approximately 14 cm × 8 cm by collimation of the roentgen beam. Fine grain, medium speed film was developed in a special developer for 35 mm film, the definition of the recording system was approximately 1.8 pair of lines per mm. The examinations were performed p.a. with the patient supine. Sedimentation of the contrast medium in the ampullar pelvis was avoided by rotating the patient before the examination. No compression of the ureters was applied.

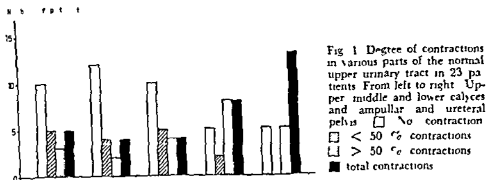


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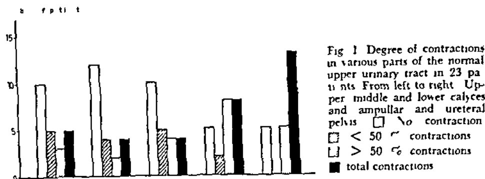


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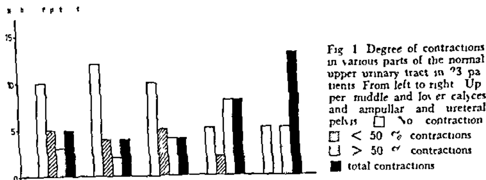


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Table 3

Duration of contraction in relation to degree of contraction 3 = total or near total contraction 2 = > 50 per cent contraction 1 = < 50 per cent contraction 0 = no contraction

Degree of contraction	No of cases	Duration of contraction (s)
3	13	7 2
1+2	8	4 63

Table 4

Contractions of upper urinary tract in relation to anatomy

Type of ampullar pelvis and calyces	No of cases	Contractions per s	Degree of contraction	Duration of contractions (s)
Ordinary	18	2 44	2 39	5 83
Bifid	4	2 5	2 25	5 75
Ampullar	1	1	2	6

The frequency degree and duration of contractions in various types of ampullar pelvis are tabulated in Table 4 No difference between the ordinary and the bifid type of ampullar pelvis was evident Only one instance of an ampullar pelvis occurred in the series so that no conclusion regarding the contractions in this type of ampullar pelvis can therefore be drawn The frequency of contractions related to their degree in various parts of the upper urinary tract appear in Table 5 and Fig 2 The most complete contractions were usually evident in the ureter and ampullar pelvis, the type seemed to be generally independent of each other One possible exception was the greater activity in the upper calyces group in patients with four contractions per minute

Discussion

The validity of the observation of contractions with a single plane cine technique was investigated by simultaneous right angle biplane cineradiography this was performed in 4 male adult cardiac patients with no symptoms or signs of disease of the urinary tract The biplane cinefilms from four separate contractions of the upper urinary tract in each patient were examined and traced frame by frame all 16 contractions proved to be concentric and symmetric This appeared to indicate that cineradiography in one plane is adequate for examining contractions of the normal upper urinary tract, it may however be possible that the contractions are asymmetric in certain pathologic conditions

Table 1

Frequency degree and duration of upper urinary tract contractions in normal men and women Type of contractions classified as follows 3 = total or near total contraction 2 = > 50 per cent contraction 1 = < 50 per cent contraction 0 = no contractions

	No of cases	Contractions per min	Degree of contraction	Duration of contraction (s)
Men	14	2	1 26	5
Women	9	3	1 64	7

Table 2

Contractions of upper urinary tract in different age groups (mean values)

Age group	No of cases	Contractions per min	Degree of contraction	Duration of contraction (s)
>40 years	6	3 0	1 70	5 50
41—55 years	12	2 29	1 45	5 92
<55 years	5	1 33	0 96	5 20

contractions in various parts of the upper urinary tract in 23 normal subjects were as follows

Upper calyces	1 13 (range 0—3)
Middle calyces	0 91 (range 0—3)
Lower calyces	1 09 (range 0—3)
Ampullar pelvis	1 83 (range 0—3)
Upper part of ureter	2 13 (range 0—3)

The most active contractions were observed in the upper part of the ureter and ampullar pelvis whereas those in the calyces were less active The contractions in 21 patients lasted from 4 to 8 s with a mean of 6 s, none occurred in the upper urinary tract during the observation period in 2 patients

The mean frequency, degree and duration of contractions are tabulated in Table 1 There was a tendency to a somewhat higher frequency of contractions in women than in men and in the former they were possibly more complete and of somewhat longer duration The frequency, the degree and duration of the contractions for different age groups appear in Table 2 There was a tendency for the frequency and degree to be somewhat lower in the older than in the younger subjects

The duration of the contractions is related to their degree in Table 3, the more complete contractions lasted somewhat longer than the others

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Frequency degree and duration of upper urinary tract contractions in normal men and women Type of contractions classified as follows 3 = total or near total contraction 2 = > 50 per cent contraction, 1 = < 50 per cent contraction 0 = no contractions

	No of cases	Contractions per min	Degree of contraction	Duration of contraction (s)
Men	14	2	1.26	5
Women	9	3	1.64	7

Table 2

Contractions of upper urinary tract in different age groups (mean values)

Age group	No of cases	Contractions per min	Degree of contraction	Duration of contraction (s)
>40 years	6	3.0	1.70	5.50
41—55 years	12	2.29	1.45	5.92
<55 years	5	1.33	0.96	5.20

contractions in various parts of the upper urinary tract in 23 normal subjects were as follows

Upper calyces	1.13 (range 0—3)
Middle calyces	0.91 (range 0—3)
Lower calyces	1.09 (range 0—3)
Ampullar pelvis	1.83 (range 0—3)
Upper part of ureter	2.13 (range 0—3)

The most active contractions were observed in the upper part of the ureter and ampullar pelvis whereas those in the calyces were less active The contractions in 21 patients lasted from 4 to 8 s with a mean of 6 s, none occurred in the upper urinary tract during the observation period in 2 patients

The mean frequency, degree and duration of contractions are tabulated in Table 1 There was a tendency to a somewhat higher frequency of contractions in women than in men and in the former they were possibly more complete and of somewhat longer duration The frequency, the degree and duration of the contractions for different age groups appear in Table 2 There was a tendency for the frequency and degree to be somewhat lower in the older than in the younger subjects

The duration of the contractions is related to their degree in Table 3, the more complete contractions lasted somewhat longer than the others

Table 3

Duration of contraction in relation to degree of contraction 3 = total or near total contraction 2 = > 50 per cent contraction 1 = < 50 per cent contraction 0 = no contraction

Degree of contraction	No of cases	Duration of contraction (s)
3	13	7 2
1+2	8	4 63

Table 4

Contractions of upper urinary tract in relation to anatomy

Type of ampullar pelvis and calyces	No of cases	Contractions per s	Degree of contraction	Duration of contractions (s)
Ordinary	18	2 44	2 39	5 83
Bifid	4	2 5	2 25	5 75
Ampullar	1	1	2	6

The frequency degree and duration of contractions in various types of ampullar pelvis are tabulated in Table 4 No difference between the ordinary and the bifid type of ampullar pelvis was evident Only one instance of an ampullar pelvis occurred in the series so that no conclusion regarding the contractions in this type of ampullar pelvis can therefore be drawn The frequency of contractions related to their degree in various parts of the upper urinary tract appear in Table 5 and Fig 2 The most complete contractions were usually evident in the ureter and ampullar pelvis the type seemed to be generally independent of each other One possible exception was the greater activity in the upper calyces group in patients with four contractions per minute

Discussion

The validity of the observation of contractions with a single plane cine technique was investigated by simultaneous right angle biplane cineradiography this was performed in 4 male adult cardiac patients with no symptoms or signs of disease of the urinary tract The biplane cinefilms from four separate contractions of the upper urinary tract in each patient were examined and traced frame by frame all 16 contractions proved to be concentric and symmetric This appeared to indicate that cineradiography in one plane is adequate for examining contractions of the normal upper urinary tract it may however be possible that the contractions are asymmetric in certain pathologic conditions

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Lower calyces	1.09 (range 0—3)
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The most active contractions were observed in the upper part of the ureter and ampullar pelvis whereas those in the calyces were less active The contractions in 21 patients lasted from 4 to 8 s with a mean of 6 s, none occurred in the upper urinary tract during the observation period in 2 patients

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Fig. 2 Mean degree of contractions in relation to frequency of contractions in various parts of the normal upper urinary tract 0 = no contraction 1 = < 50 % contraction 2 = > 50 % contraction 3 = total contraction From left to right One two three and four contractions per minute respectively upper calyces middle calyces lower calyces ampullar pelvis ureteral pelvis

as possible Some differences however inevitably occurred The diuresis may for example have varied Contractions of the ureter and renal pelvis are not affected by moderate changes in diuresis (cf KIIL) Nor is there any evidence in previous work that the drugs given to some of the patients particularly long term medication with diuretics influence the contractions

The contractions usually started in the upper part of the ureter or in this situation and the ampullar pelvis simultaneously BECKER & POLLACK made similar observations DUX et coll stated that the contractions of the upper urinary tract were essentially concentric but failed to indicate their starting point The present findings are in agreement with previous pressure measurements (KIIL inter alios) that suggested that the ureteric pelvis plays an important active role in the emptying of the upper urinary tract It seems that the ureteric pelvis usually acts as a pace maker for the contractions, however in 4 out of 21 patients the contractions started in the upper urinary tract other than in the lower part of the ampullar pelvis or the ureteric pelvis

During surgery KIIL observed that the contractions started in the ampullar pelvis and upper part of the ureter and this was confirmed in the present investigation The changes in outline of the ampullar pelvis from filling to emptying phase observed during surgery have been explained as mostly due to changes in distribution of the contents of the ampullar pelvis The cineradiographic investigations seemed to make it clear that often this cannot occur, particularly when contractions of the upper urinary tract are complete or almost complete

The degree of contraction varied considerably The highest average was recorded in the ureteric and ampullar pelvis whereas the calyces on the average produced lesser contractions although the individual variations were considerable No dilatation of the calyces was apparent when the ampullar pelvis or the ureteric pelvis contracted This is in agreement with the findings of DUX et coll but not with those of BECKER & POLLACK Sphincteric action in the calyceal neck

Table 5

Frequency and degree of contractions in various parts of the upper urinary tract

Contractions per min	No. of cases	Upper calyces	Middle calyces	Lower calyces	Ampullar pelvis	Upper part of ureter
0	2	—	—	—	—	—
1	6	1.17	1.17	1.33	1.67	1.83
2	3	0.67	0.67	0.67	2.33	2.67
3	8	0.75	0.63	0.75	1.88	2.38
4	3	2.67	2.0	2.0	2.33	2.67
7	1	3.0	—	3.0	3.0	3.0

The length of the cine recordings represents a compromise between various technical and radiation dose considerations. Even with pulsed cineradiography, long recordings put a high thermal load on the roentgen tube and necessarily limits their length. The load on the tube and the radiation dose to the patient may be reduced by employing a low frame frequency for the cine recordings. The 20 frames per second used in the present investigation were more than adequate to record the relatively slow contractions of the ampullar pelvis. However, with a frame frequency below 20, the respiration movements become disturbing and it is nearly impossible to examine the film when it is running continuously; this makes the interpretation and analysis of detail difficult. On the other hand a time lapse technique with, e.g. 2 exposures per second, would be suitable for detecting any extended variations in the frequency of the contractions.

The skin dose to the dorsum in the center of the field of radiation was small in relation to that received in ordinary urography. The radiation dose to the ovary was low in 2 of the patients in whom it was measured and actually within the error of the method. A dose of 41 to 57 mrad/min was recorded in the third patient, only a fraction of the dose of 1 320 to 1 430 mrad received in ordinary urography (LARSSON 1958). These measurements suggest that the present technique may be used with only a minimal radiation dose to the gonads. A further reduction in the radiation dose would be possible with videotape or video disc recording; increasing experience may make such recordings in combination with a time lapse technique fully adequate.

Respiration failed to influence the contractions of the upper urinary tract; this is in agreement with BECKER & POLLACK but not with DUX et coll.

The possible effect of the position of the patient on the contraction was not investigated. Previous pressure (KIIL) and cineradiographic (BECKER & POLLACK) trials have failed to disclose that it is of any importance. The degree of dehydration, the diuresis and the examination technique were kept as uniform



Fig. 2. Mean degree of contractions in relation to frequency of contractions in various parts of the normal upper urinary tract. 0 = no contraction. 1 = < 50 % contraction. 2 = > 50 % contraction. 3 = total contraction. From left to right: One, two, three and four contractions per minute respectively. ☐ upper calyces, ☐ middle calyces, ☐ lower calyces, ☐ ampullar pelvis, ■ ureteral pelvis.

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was considered likely by DUX et coll but not confirmed by BECKER & POLLACK No indications of an anatomic or functional sphincter in this area were observed in the present investigation

The number of contractions per minute varied from 0 to 7 The most frequent contractions usually occurred in the upper part of the ureter and ampullar pelvis whereas the calyces presented a lesser degree of contraction The more frequent contractions tended to be somewhat more complete than those less frequent, although the difference was not marked The contractions tended to be higher and their degree more complete in the younger patients and in women more than in men, the differences however were not significant The frequency of the contractions in this material is in agreement with the findings of BECKER & POLLACK, other investigators have not given figures The interval between the contractions and their duration remained constant during the observation period in the same patient Similarly their degree in different parts of the urinary tract remained unaltered It appeared that the type of contraction in each patient was the same

No contractions were noted in the upper urinary tract during the observation period in 2 patients Nor were any contractions evident during additional intermittent fluoroscopy over a period of 30 minutes These 2 patients did not differ systematically from the remainder Whether they represent a group that normally has no or only minimal contractions of the upper urinary tract, whether they were in a period of asystole of the upper urinary tract, or whether the inactivity was due to some unknown factor induced by treatment or the examination procedures remains conjectural Similar observations have been made by BECKER & POLLACK who observed no motor activity in 10 of 34 cineradiographic investigations of the upper urinary tract They attributed most of these findings to poor filling of the ampullar pelvis in patients examined a long time after the injection of the medium The contrast filling of the upper urinary tract and the technical quality of the cineangiograms in the 2 patients of the present material was good

Pressure measurement in the renal pelvis by KIIL and others have indicated that no characteristic pressure fluctuations in the calyces occur, he also reported only slight and uncertain pressure variations in the ampullar pelvis, in contrast to the relatively high amplitude of pressure variations that occur in the ureter KIIL's investigation suggests that the transport of urine through the ampullar pelvis takes place with only slight pressure variations However in the present and other cineradiographic investigations considerable variations in volume of the upper urinary tract were evident It is surprising that the sometimes considerable and nearly complete contractions of the upper urinary tract should not be accompanied by pressure variations, it may be that transportation of urine

occurs with different pressure characteristics in different patients A combina tion of cineradiography of the upper urinary tract with pressure flow measurements might be helpful

Previous investigations have indicated that there is a definite difference in the contraction between bifid and normal types of ampullar pelves Only four of the renal pelves in this material were bifid and these did not differ in the number of contractions per second in their degree nor their duration from the ordinary type of renal pelvis

SUMMARY

The contractions of the normal upper urinary tract were investigated with urography and cineradiography in 23 patients They were symmetric and followed a constant pattern in each patient The degree and frequency of the contractions varied between different patients and parts of the upper urinary tract but were mostly highest in the ureteric pelvis

ZUSAMMENFASSUNG

Die Kontraktionen der normalen oberen Harnwege wurden bei 23 Patienten durch Urographie und Kinematographie untersucht Diese waren symmetrisch und folgten einem gewissen Typus bei jedem Patienten Das Ausmass und die Frequenz der Kontraktionen waren bei verschiedenen Patienten und den verschiedenen Abschnitten der oberen Harnwege unterschiedlich jedoch am hochsten im Conus des Ureters

RÉSUMÉ

Les auteurs ont etudie par urographie et cineradiographie sur 23 sujets les contractions des voies urinaires supérieures normales Elles sont symetriques et suivent un schema constant chez un meme sujet L intensite et la frequence des contractions varient d un sujet a l autre et suivant les differentes parties des voies urinaires superieures mais c est en général au niveau du cone ureteral qu elles sont le plus intenses

REFERENCES

BECKER J A and POLLACK H Cinefluorographic studies of the normal upper urinary tract Radiology 84 (1965) 886

CATEL W und GARSCHE R Studien bei Kindern mit dem Bildwandler Forstschr Röntgenstr 86 (1957) 66

DUX A THURN P und KISSELER B Der physiologische Entleerungsmechanismus der ableiten den Harnwege im Rontgenkinematogramm Fortschr Röntgenstr 97 (1962) 687

KILL F The function of the ureter and renal pelvis Saunders Co Philadelphia and London 1957

LARSSON L E Radiation doses to the gonads of patients in Swedish roentgen diagnostics Acta radiol (1958) Suppl No 157

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Table 1

The relation between the duration of the disease and the examination

	Duration of disease before first examination	Interval between first and second examination	Interval between second and third examination
1 year	5	6	4
2 –5 years	4	5	1
5—10 years	5	3	

chyma (COMFORT et coll 1946 GAMBILL et coll 1948 1960 SARLES et coll 1965) The risk of complications such as pseudocysts acute hemorrhagic pancreatitis and severe gastrointestinal bleeding is considerable during its course A group of patients that had repeat angiographic examinations at varying intervals was selected from a material of chronic pancreatitis in order better to understand the vascular changes that occur at the different stages

Material and Method The group elected consisted of 14 patients made up of 10 men and 4 women with chronic pancreatitis all examined twice and 5 patients a third time as well a total of 33 examinations were performed The diagnosis was verified by operation in 13 of the patients and further confirmed by pathology in 7 patients The fourteenth patient had classical chronic pancreatitis with at least ten acute exacerbations for which she had needed hospital treatment for ten years she also had decreased exocrine pancreatic function, cholecystography was normal

The relation between the examinations and the duration of the disease appears in Table 1 The time from its beginning to the first examination is difficult to evaluate as most of the patients had had abdominal pain of gradual onset for many years

Diabetes mellitus was evident at the first examination in 3 patients but in the later examinations had developed in another 4 patients The exocrine pancreatic function was investigated in 7 patients and proved to be reduced in all Calcifications were present in the pancreas in 3 patients at the first examination and in a further 3 patients at the repeat

Twelve patients were examined with injection into both the celiac and the superior mesenteric arteries either simultaneously or separately Only the celiac axis was injected at both examinations in 1 patient and at the repeat examination in a further patient Norepinephrine bradykinin and vasopressin were used in some of the patients to obtain better information regarding the pancreatic vessels (BOIJSEN & REDMAN 1966 1967 BOIJSEN & GOTHLIN)

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR: PROF. O. OLSSON),
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VASCULAR CHANGES IN CHRONIC PANCREATITIS

by

ERIK BOIJSEN and ULF TYLÉN

The diagnosis of carcinoma of the pancreas and chronic pancreatitis is often difficult. Should surgery be contemplated or decided upon, an accurate differentiation between these conditions is important since even at operation this may not be easy (GLENN & THORBJARNARSON 1964). Angiography has become almost the only simple means of investigating the pancreas.

Much work has been done to try to differentiate the angiographic findings in carcinoma of the pancreas from those in chronic pancreatitis since ÖDMAN (1958) suggested that chronic pancreatitis might present special vascular changes. Some investigators of angiography in pancreatic disease have reported it possible to make a diagnosis with a high degree of accuracy (HERNANDEZ et coll. 1967, SAMMONS et coll. 1967, RÖSCH & BRET 1965, LECHNER & POKIESER 1971) while others have been less confident (RANNIGER & SALDINO 1966, NEBESAR & POLLARD 1967). Only a few authors have stated that diagnostic difficulties seldom arise since vascular changes in both conditions are characteristic (REUTER et coll. 1969, 1970, BOOKSTEIN et coll. 1969). Opinions regarding the angiographic findings in chronic pancreatitis thus range from the normal to marked vascular changes.

Chronic pancreatitis is a progressive condition with calm periods and acute exacerbations that ultimately leads to total destruction of the pancreatic paren-

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Results

Displacement of arteries within or surrounding the pancreas was present in 8 patients at the first examination (Figs 1 a, 2 a), which at operation proved to be caused by an abscess (2), pseudocyst (2), multiple small cysts (2) and an enlarged, indurated pancreatic head (1), the eighth patient had an enlarged, indurated pancreatic head as well as edema from an acute exacerbation of pancreatitis

The displacement of arteries had disappeared or was markedly reduced at repeat examinations in 6 patients who had been operated upon (Fig 2 b) No change compared to the first examination was evident in one patient with displacement due to multiple cysts in the enlarged pancreatic head and the appearances were the same at the third examination one year later The displacement remained but was slightly reduced in a patient who had no operation

Marked displacement to the left of the pancreatic vessels and the gastroduodenal artery was present in 2 patients at the first examination In one of these the displacement disappeared when the body and tail of the pancreas had been resected, in the other it persisted and had progressed in 2 other patients (Figs 3, 7) Another patient had at the repeat examination one year later developed marked displacement of the vessels around the tail of the pancreas considered at operation to be due to a pseudocyst (Fig 4 b)

A short membrane like stenosis proximally in the common hepatic artery was evident in 2 patients, this had disappeared completely at repeat examination (Fig 1), but in one the same type of changes was now present in the left gastric artery The same type of stenosis was recorded in the left inferior phrenic artery in another patient but had also disappeared at the second examination One patient in whom the splenic artery arose from the aorta had this type of stenosis at two successive examinations

A smooth stenosis of slightly varying lumen over a short or long segment of a large artery was evident in 7 of the patients The lumen might be markedly reduced but there was never total occlusion The stenosis occurred and terminated abruptly (Figs 2, 3, 4, 5) Such changes affected the splenic artery in 6 patients, the common hepatic artery in 3, the gastroduodenal artery in another 3 and the superior mesenteric artery in one patient Stenosis in 2 or more arteries was present in 4 patients The changes had disappeared in 4 of the patients at the second examination In 2 of these an abscess had been removed (Fig 2) and in one patient with alterations in the gastroduodenal artery these had disappeared because the artery had been ligated The changes of this type had disappeared completely in the last patient in spite of the fact that he had not been operated upon and the pancreatic arcades were displaced to the same extent The changes at the repeat examination had increased in 2 patients, the progress was marked

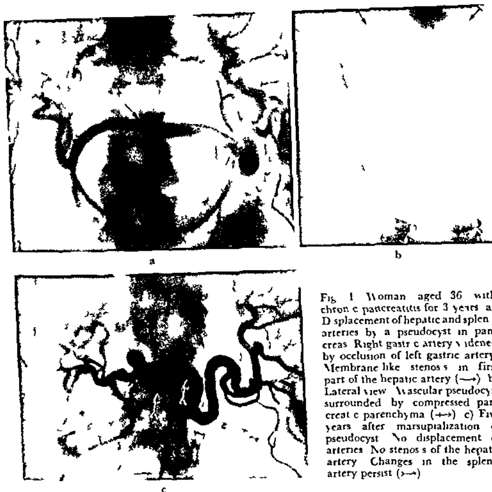


Fig 1 Woman aged 36 with chronic pancreatitis for 3 years a) Displacement of hepatic and splenic arteries by a pseudocyst in pancreas Right gastric artery widened by occlusion of left gastric artery Membrane like stenosis in first part of the hepatic artery (⟶) b) Lateral view Vascular pseudocyst surrounded by compressed pancreatic parenchyma (↔) c) Five years after marsupialization of pseudocyst No displacement of arteries No stenosis of the hepatic artery Changes in the splenic artery persist (>⟶)

in one of the e and was still more accentuated at the third examination (Fig 3)

Another type of stenosis was apparent in 5 patients This consisted of smooth tapering over a long segment of an artery without the artery giving off corresponding branches (Fig 5) The stenosis was always smooth and was located in the gastroduodenal artery (2) and the splenic artery (3) The same type of stenosis also occurred in the superior mesenteric artery in one of the patients with splenic artery involvement The tapered stenosis had disappeared from the splenic artery at repeat examination after removal of a closely related abscess in one patient (Fig 2) in the others it was unaltered and in one patient even progress of the changes in the common hepatic artery was evident (Fig 5 b) A further 2 patients had developed changes in the gastroduodenal artery and



Fig. 2. Man aged 48 with palpable tumour in epigastrium. a) Displacement of the hepatic, gastroduodenal and colic arteries by an abscess (—). Smooth tapering stenosis of splenic artery (↔). Pancreatic arcades slightly irregular with a beaded appearance. b) One year after the abscess was drained. Neither arterial displacement nor changes in the splenic artery. Arteries in head of pancreas still irregular.

one patient had an affected splenic artery. (Details of arterial stenosis appear in Table 2.)

Marked stenosis of the celiac artery at its origin at the aorta was present in 2 patients. This appeared as if caused by the median arcuate ligament of the diaphragm and remained completely unchanged from one examination to another. These changes probably bore no relation to chronic pancreatitis. There was never direct or indirect suggestion of malignancy in the outlines of the arteries.

An arterial aneurysm was evident in 3 patients. This was located in the splenic artery in 2 patients and in one of whom it had increased in 7 years from 2 mm to 5 mm in diameter (Fig. 6). The other patient had previous to the second examination been operated upon for bleeding into the pancreatic duct from the ruptured aneurysm; in the third patient an aneurysm developed postoperatively in the gastroduodenal artery (Fig. 5).

Tortuous arteries of slightly varying lumen similar to those in fibrous dysplasia were observed in all patients but one. This type of change was most common in the small arteries: the pancreatic arcades, the dorsal pancreatic artery, the transverse artery and the arteries of the tail of the pancreas. The changes varied slightly from one examination to another (Figs. 2, 3). Increased tortuosity was also present in the middle colic artery, especially in its left part. Five patients exhibited these changes which had increased markedly at later examinations

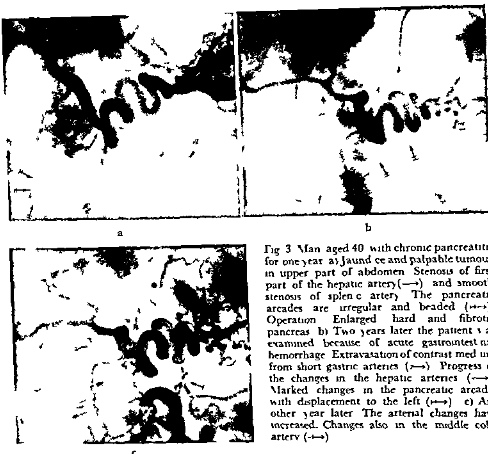


Fig 3 Man aged 40 with chronic pancreatitis for one year a) Jaundice and palpable tumour in upper part of abdomen Stenosis of first part of the hepatic artery (⟶) and smooth stenosis of splenic artery The pancreatic arcades are irregular and beaded (↦) Operation Enlarged hard and fibrotic pancreas b) Two years later the patient was examined because of acute gastrointestinal hemorrhage Extravasation of contrast medium from short gastric arteries (↣) Progress of the changes in the hepatic arteries (⟶) Marked changes in the pancreatic arcades with displacement to the left (↦) c) Another year later The arterial changes have increased. Changes also in the middle colic artery (⟼)

(Fig 7) The changes developed during the course of the disease in another 3 patients they also occurred in the first jejunal artery in one patient

Because of the large normal variations it was not possible to evaluate accurately the vascularization of the pancreas but it seldom seemed to be normal in all parts of the pancreas at all the examinations The vascularization had decreased in 8 patients had increased in 3 and was unchanged between the examinations in 3 patients

Lesions of the veins close to the pancreas were common At the first examination compression of the splenic and superior mesenteric veins was recorded in 3 patients (Fig 8) 2 of whom also had changes in the portal vein Compression of only the superior mesenteric vein was evident in one patient (Fig 6 c) and complete occlusion of the splenic vein in 5 patients Neither the splenic nor the superior mesenteric vein was revealed in 4 patients but as there were no signs of



Fig. 4. Woman aged 39 with chronic pancreatitis and acute exacerbations for 2 years. a) Long smooth stenosis of splenic artery. Hypervascularization of tail of pancreas with wide arteries. b) Examination one year later for abdominal pain and hematemesis. Pseudocyst with medial displacement of spleen. Hypovascularization of tail of pancreas. At both examinations an atypical calcification lay at the hilum of the spleen (→) and which at operation was located in the wall of a small cystadenoma.

Table 2

Stenosis of arteries at the different examinations. CH Common hepatic artery. Gd Gastroduodenal artery. LG Left gastric artery. LH Left hepatic artery. RH Right hepatic artery. S Splenic artery. SM Superior mesenteric artery

Case	Examination		
	First	Second	Third
1	RH Gd S	Gd	
2	S Gd	S LG Gd	S Gd
3	S Gd SM	SM CH S	SM
4	S Gd	LH S Gd SM	
5	—	RH	
6	—	—	RH
7	—	Gd	Gd S
8	CH S	Gd	
9	—	S	
10	—	—	
11	RH	S	
12	S	—	
13	CH S Gd	CH S Gd SM	CH RH LH S Gd
14	S	S	



Fig 5 Man aged 54 chronic alcoholic with abdominal pain a) Barium examination revealed displacement of the duodenum Enlargement of head of pancreas with long smooth regular stenosis with slightly varying lumen of gastroduodenal artery (—→) Changes also in the splenic artery (↦→) The right hepatic artery was ligated probably at previous cholecystectomy (→→) b) Four months later after marsupialization of three small pseudocysts in head of pancreas The gastroduodenal artery was ligated an aneurysm had developed in its distal end (→) Progress of changes in the splenic artery (↦→)

collaterals this was regarded as due to an insufficient technique and the vein was consequently recorded as patent The second examination of these patients with venous abnormalities demonstrated that 2 were improved (one was normal) 3 were unchanged and progress was noted in 4 patients 5 patients had normal veins at both examinations

None of the 5 patients with advanced diseases who were examined three times had normal veins at the last examination The spleen had been removed in 3 compression of the splenic vein was evident in one and occlusion in one patient Two of the patients had compression of the superior mesenteric vein and one of the portal vein as well One of the patients also had occlusion of some of the intrahepatic portal vein branches

Splenoportal phlebography in 3 patients verified previous findings at angiography

Discussion

HERNANDEZ et coll (1967) described three types of arterial changes in chronic pancreatitis These authors described a short stenosis like a diaphragm, located mainly in the celiac or the left gastric arteries or somewhat less often in the splenic or hepatic arteries in 20 per cent of their patients The stenosis was usually located in the first centimeter of the artery This type of stenosis

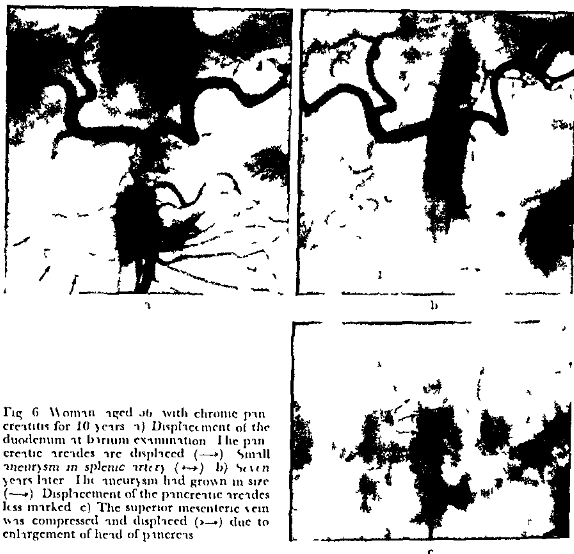


Fig. 6. Woman aged 56 with chronic pancreatitis for 10 years. a) *Displacement of the duodenum at barium examination.* The pancreatic arcades are displaced (—→). Small *aneurysm in splenic artery* (↔). b) *Seven* years later. The aneurysm had grown in size (—→). Displacement of the pancreatic arcades less marked. c) The superior mesenteric vein was compressed and displaced (>—→) due to enlargement of head of pancreas.

corresponds to that evident in 5 of the present patients (Fig. 1 a). The stenosis was inconstant and regarded as caused by spasm induced by the tip of the catheter; *it seems however to be present more often in chronic pancreatitis than* in other conditions.

One type of stenosis described by HERNANDEZ et coll. as cone shaped, and another long, concentric type of stenosis with regular walls like a sleeve round the artery was reported by REUTER et coll. These arterial changes were regarded by the former authors as pathognomonic of chronic pancreatitis. They frequently occurred in the present material (Figs. 2, 3, 4, 5) and suggest atheromatosis from which they cannot be distinguished even by the pathologists. The changes can therefore hardly be regarded as pathognomonic of chronic pan-



Fig 7 Man aged 3? with chronic pancreatitis for one year a) Normal course of middle colic artery b) Two years later after splenectomy and drainage of an abscess the superior mesenteric artery was displaced to the left The middle colic artery was irregular and tortuous (⟶) c) A further two years later The displacement increased The middle colic artery was more tortuous and changes also in the hepatic artery were evident

creatitis even if their location in arteries in close relation to the pancreas strongly indicates disease of this gland These changes in patients with generalized atheromatosis are not so characteristic as to permit of a definite diagnosis in chronic pancreatitis they seem to be reversible since they disappeared at repeat examination in 3 out of 8 patients (Fig 2)

The changes described by REUTER et coll as smooth beaded alternation of arterial narrowing and dilatation together with an increased tortuosity were evident in most of the patients of the present material (Figs 2 3) The changes

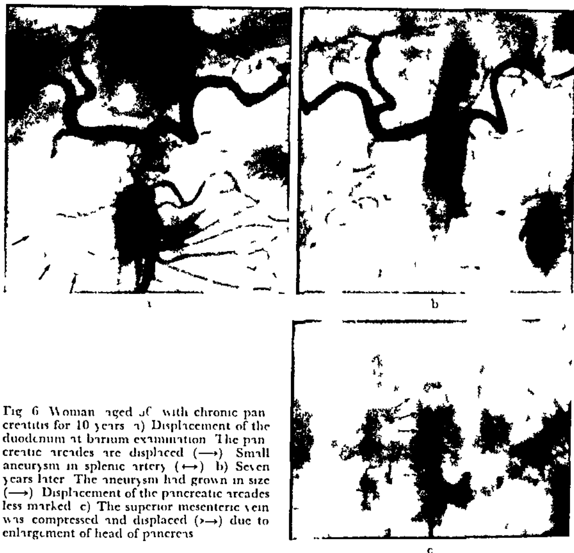


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patients in the first jejunal artery which in the same way might explain the sentinal loop in acute pancreatitis

The leakage of enzymes is probably also the cause of the development of retroperitoneal adhesions, which cause increasing displacement of the pancreas and its vessels upwards to the left resulting in concomitant displacement of the gastroduodenal artery (Fig 3) The disappearance of the displacement in one of the patients after resection of the body and tail of the pancreas supports the theory Displacement of arteries in this part of the abdomen is difficult to evaluate because of the great variability in the anatomy (MICHELS 1955 ÖDMAN 1958) Marked displacement of several arteries does however, permit the diagnosis of expansive lesions Such lesions in the present material have always been of low vascularization and usually proved at operation to be pseudocysts or abscesses A large expansivity surrounded by a hypervascular rim of tissue was evident in one patient this might have been the same as that described by HERNANDEZ et coll and termed by them lymphangiome kystique After marsupialization of the pseudocyst in the present material some hypervascularization but no displacement of vessels remained (Fig 3)

The complete disappearance of arterial stenosis in a few of the patients after operation is difficult to explain (Fig 2) The inflammatory process is slowed and the cause of pressure on the arterial walls disappears after removal of a pseudocyst or an abscess although this alone cannot explain the disappearance of the changes if they were of organic nature only There might also be increased irritability of the arterial wall producing spasm on the injection of contrast medium This might also explain the inconstancy of the membrane like stenosis in some of the patients and the increased tendency to constriction of pancreatic vessels after epinephrine (BOIJSEN & REDMAN 1967)

Evaluation of the vascularization of the pancreas is difficult A close relationship between the activity of the disease as evaluated from clinical data and the vascularization was not observed in most of the patients although it should be pointed out that the latter was not normal in any of the patients One of them was specially interesting in that at the first examination she had marked hypervascularization of the tail of the pancreas where one year later a pseudocyst developed (Fig 4) Hypovascularization in some of the patients could be correlated to the hard sclerosing type of chronic pancreatitis present at operation the mottled appearances due to hypervascularization reported by ÖDMAN was not observed in this material

The arterial changes in the series were marked as the patients had advanced disease A certain type of arterial abnormality should be pointed out as perhaps being characteristic of chronic pancreatitis i e increased tortuosity and beaded appearances of the small arteries of the pancreas The findings of the writers are

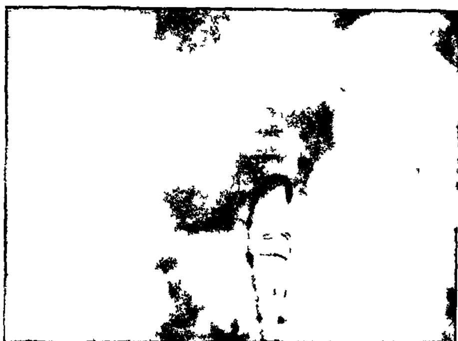


Fig. 8. Man aged 42, chronic alcoholic, with chronic pancreatitis and oesophageal varices. Expansive lesion in body and tail of pancreas compressing the superior mesenteric vein and occluding the splenic vein. Collateral veins in the fornix of the stomach.

are similar to those in fibrous dysplasia but different from encasement and infiltration as in carcinoma of the pancreas which were not observed in the series; no tumour vessels were apparent. The changes were located in the pancreatic arcades, the transverse pancreatic artery and other small arteries in the tail of the pancreas, and were often present at the same time in the head as well as in the body and tail of the pancreas; this meant that the whole gland was affected. The alterations often increased between the examinations and in this respect it was interesting to find aneurysms in 3 patients (Figs 5, 6 b); the risk of their development has already been pointed out (BOIJSEN et coll. 1969, KADELL & RILEY 1967). The growth of one aneurysm and the rupture of another in this material indicates the importance of control examinations.

Localized dilatation of the transverse colon in acute pancreatitis is common (BRASCHO et coll. 1967) and benign strictures at the same site have been described in chronic pancreatitis (REMINGTON 1947); these are believed to be caused by leakage of enzymes into the mesocolon. It is therefore important to look for alterations in the middle colic artery; this artery normally pursues a direct course up to the splenic flexure although in the present material it was often tortuous with a slightly irregular lumen. The changes in many of the cases had obviously progressed (Fig. 7). Alterations also occurred in one of the

present in all the patients and perhaps characteristic of chronic pancreatitis, help to distinguish this condition from atheromatosis

The progressive arterial changes with development of aneurysms as well as the progress of venous occlusions indicates the necessity of repeat examinations to discover a potential source of gastrointestinal hemorrhage in due time A control examination should also be made as soon as surgery is considered in order to help in choosing the appropriate method of therapy

Acknowledgement

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SUMMARY

Fourteen patients with chronic pancreatitis subjected to repeat angiographic investigations had evidence of arterial changes that were different from those in carcinoma of the pancreas but much like those in atheromatosis The changes sometimes disappeared but usually progressed in spite of operation that was performed in 13 subjects No obvious correlation was obtained between the duration of the disease and the degree of vascular change

ZUSAMMENFASSUNG

Vierzehn Patienten mit chronischer Pankreatitis die wiederholten angiographischen Untersuchungen unterworfen wurden hatten Zeichen arterieller Veranderungen die sich von denen bei Pankreaskarzinom unterschieden jedoch denen bei Artheromatosis sehr ahnlich waren. Diese Veranderungen verschwanden gelegentlich verstarkten sich jedoch gewohnlich trotz einer Operation die bei 13 Personen vorgenommen wurde Es fand sich keine klare Korrelation zwischen der Dauer der Erkrankung und dem Grad der Gefassveranderungen

RÉSUMÉ

Des angiographies repetees chez quatorze malades atteints de pancreatite chronique ont montre des lesions artérielles qui etaient differentes de celles du cancer du pancreas mais qui ressemblaient beaucoup à celles de l atheromatose Ces lesions ont disparu dans certains cas mais habituellement elles ont progresse malgre l operation qui avait ete faite chez 13 patients Les auteurs n ont pas trouve de correlation evidente entre la duree de la maladie et l degre des lésions vasculaires

REFERENCES

BOIJSEN E and REDMAN H C. Effect of bradykinin on celiac and superior mesenteric angiography Invest Radiol 1 (1966) 422

— — Effect of epinephrine on celiac and superior mesenteric angiography Invest Radiol 2 (1967) 184

the same as those of REUTER et coll. The vascular abnormalities were located in the whole pancreas and to a certain extent in vessels remote from the pancreas as well. Such changes may usually be distinguished from those in carcinoma of the pancreas in which disease they are most often localized (LUNDERQUIST 1965). If carcinoma involves the entire pancreas the arterial changes are far more marked than in chronic pancreatitis. The individual arterial signs in these patients never presented differential difficulties although the group selected is too small to be conclusive.

REUTER et coll. had a low frequency of venous lesions in their material. The present authors, in contrast, observed occlusion or compression of the veins in almost all the patients. This, however, may be explained by the fact that all the patients had advanced disease. The venous changes in chronic pancreatitis are usually unspecific (ROSCH 1965). Compression or occlusion of the vein may be caused by expansivity, pseudocyst, abscess, simple enlargement of the pancreas or malignancy. The steady progress of the disease is well illustrated in the veins, as for example in the patient who at the first examination had a normal splenic vein that two years later became occluded in spite of marsupialization of a pseudocyst diagnosed at the first examination. It seems as if the venous compression may at first be reversible and therefore patients in whom this has been diagnosed should be operated as soon as possible; this will avoid total venous occlusion that sooner or later leads to severe gastrointestinal bleeding.

This investigation suggests that chronic pancreatitis is a progressive disease. This is in accord with REUTER et coll. who observed more marked changes in patients with chronic pancreatitis and a history of the disease for more than two years. Operation may relieve the immediate symptoms but the course of the disease is unchanged as evident from the angiographic signs. The speed of progress may however vary and little correlation exists between the duration of the disease and the degree of vascular alterations. One of the patients for example went for seven years between two examinations. In the meantime calcifications had appeared in the pancreas indicating progress although only a slight increase in the vascular signs was apparent. On the other hand 2 patients, each examined on three occasions in one year, presented evidence of steady progress in the vascular changes from one examination to the next. Further investigations in larger materials may help to clarify this enigma.

In conclusion certain arterial changes may be anticipated in chronic pancreatitis, changes that are different from those evident in carcinoma of the pancreas, although like those in atheromatosis. It should therefore not be difficult to differentiate chronic pancreatitis from carcinoma of the pancreas although the diagnosis may be difficult in patients with generalized atheromatosis. The changes in small arteries with slightly varying lumen and increased tortuosity,

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ANGIOGRAPHY IN THE DIAGNOSIS OF DUODENAL LESIONS

I Differentiation between primary duodenal carcinoma and carcinoma of the head of the pancreas involving the duodenum

by

OLLE OLSSON

The necessity of a correct differential diagnosis between a lesion requiring surgical approach and one suggesting conservative treatment is obvious This holds also for conditions in which operation is indicated and those in which it may be contemplated Lesions requiring surgery for example primary carcinoma of the duodenum and carcinoma of the pancreas encroaching upon the duodenum are obviously better approached surgically if correctly diagnosed

The author has examined a series of patients with lesions in different parts of the duodenum The changes in barium meal examinations have often been the same in quite different pathologic conditions for instance carcinoma benign ulceration inflammation and vascular lesions The changes have often also been of a type making it impossible to decide whether a tumour has arisen primarily in the duodenum or pancreas

Research on angiography in the diagnosis of carcinoma of the pancreas (LUNDERQUIST 1965 OLSSON 1965 1970) and primary carcinoma of the

Submitted for publication 15 February 1971

— and Gothlin J Vasopressin in angiography of abdominal arteries To be published
— — Hallbook T and Sandblom Ph Preoperative angiographic diagnosis of bleeding aneurysms of abdominal visceral arteries Radiology 93 (1969) 781
Bookstein J J, Reuter S R and Martel W Angiographic evaluation of pancreatic carcinoma Radiology 93 (1969) 757
Brascho D J, Reynolds T N and Zanca P The radiographic colon cut off sign in acute pancreatitis Radiology 79 (1962), 763
Comfort M W Gambill L E and Baggenstoss A H Chronic relapsing pancreatitis a study of 29 cases without associated disease of the biliary or gastrointestinal tract Gastroenterology 6 (1946), 239, 376
Gambill E E, Comfort W M and Baggenstoss A H Chronic relapsing pancreatitis an analysis of 27 cases associated with disease of the biliary tract Gastroenterology 11 (1948), 1
— Baggenstoss A H and Priestley J B Chronic relapsing pancreatitis Fate of fifty six patients first encountered in the years 1939 to 1943 inclusive Gastroenterology 39 (1960) 404
Glenn F and Thorbjarnarson B Carcinoma of the pancreas Ann Surg 159 (1964) 945
Hernandez Ch, Fcarlat B et Bismuth V L artériographie des affections pancréatiques J Radiol 48 (1967) 327
Kadell B M and Riley J M Major arterial involvement by pancreatic pseudocysts Amer J Roentgenol 99 (1967) 632
Leichner G und Pokieser H Ergebnisse angiographischer Untersuchungen bei Pancreatitis Fortschr Röntgenstr 114 (1971) 19
Lunderquist A Angiography in carcinoma of the pancreas Acta radiol (1965) Suppl No 235
Michels N A Blood supply and anatomy of the upper abdominal organs J B Lippincott Co Philadelphia 1955
Nebesar R A and Pollard J J A critical evaluation of selective celiac and superior mesenteric angiography in the diagnosis of pancreatic diseases particularly malignant tumor facts and artefacts Radiology 89 (1967) 1017
Ödman P Percutaneous selective angiography of the celiac artery Acta radiol (1958) Suppl No 159
Rannicer K and Saldino R M Arteriographic diagnosis of pancreatic lesions Radiology 86 (1966) 470
Remington J H Mayo C W and Dockerty M B Stenosis of the colon secondary to chronic pancreatitis Proc Mayo Clin 22 (1947) 260
Reuter S R Redman H C and Joseph R R Angiographic findings in pancreatitis Amer J Roentgenol 107 (1969) 56
— — and Bookstein J J Differential problems in the angiographic diagnosis of carcinoma of the pancreas Radiology 96 (1970) 93
Rosch J Die Splenoportographie in der Diagnostik der Pancreaserkrankungen Radiologe 5 (1965) 274
— and Bret J Angiography of the pancreas Amer J Roentgenol 94 (1965) 182
Sammons B P Neal M P Armstrong R H and Hager H D Ten years experience with celiac and upper abdominal superior mesenteric arteriography Amer J Roentgenol 101 (1967) 345
Sarles H Sarles J C Camatte R et coll Observations on 205 confirmed cases of acute pancreatitis recurring pancreatitis and chronic pancreatitis Gut 6 (1965) 545

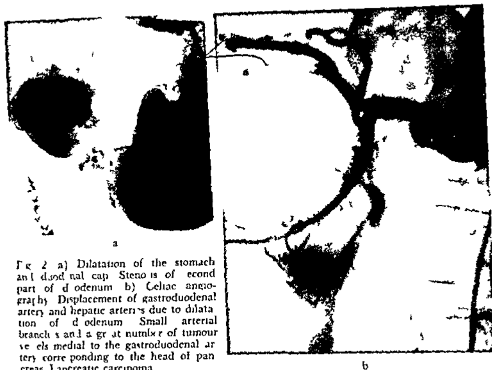


Fig 2 a) Dilatation of the stomach and duodenal cap Stenosis of second part of duodenum b) Celiac angiography Displacement of gastroduodenal artery and hepatic arteries due to dilatation of duodenum Small arterial branches and a great number of tumour vessels medial to the gastroduodenal artery corresponding to the head of pancreas Pancreatic carcinoma

SALIK 1961 LARSEN & PEDERSEN 1966, PEREZ et coll 1965 RUSSELL & MARGULIS 1965) These authors appear to have omitted to discuss the possibility of carcinoma of the head of the pancreas causing other types of changes in the duodenum and on the other hand the possibility of other lesions causing corresponding changes although such effects produced by primary carcinoma of the duodenum are mentioned by LARSEN & PEDERSEN and SALIK The latter, in his consideration of the differential diagnosis described a patient with carcinoma of the duodenum with appearances resembling those of carcinoma of the pancreas

Peripapillary changes in the medial part of the duodenal loop often occur in carcinoma of the head of the pancreas in addition to stricture distension or stenosis of the duodenum

This paper will deal with 7 patients with carcinoma of the pancreas in whom a barium meal examination suggested primary duodenal carcinoma The final diagnoses were Carcinoma of the pancreas (4), hepatic metastases of adenocarcinoma probably from the pancreas (1) and doubtful but probably carcinoma of the pancreas (2)



Fig 1 Case 1 a) Large irregular ulcer caudally in distal part of duodenal cap with a sharply defined border b) Combined celiac and superior mesenteric angiography Encroachment upon proximal part of gastroduodenal artery and pancreaticoduodenal arteries corresponding to head of pancreas Carcinoma of pancreas

duodenum (Olsson 1968, 1971) has suggested the possibility of certain criteria being used Angiographic characteristics have been presented in the two groups mentioned, and their validity will be tested in this paper An attempt will be made in the present paper to evaluate the differences in the angiographic appearances between primary duodenal carcinoma and carcinoma of the pancreas involving the duodenum and causing duodenal changes of a type that makes it impossible by conventional roentgen examination to differentiate between these conditions A wider angiographic differential diagnosis will be discussed in a later paper (part II) and the angiographic features of benign tumours and non malignant duodenal lesions will be exemplified

Frostberg (1938) described a characteristic deformity in the concavity of the second part of the duodenum caused by enlargement of the head of the pancreas in 2 patients by carcinoma and in one patient by pancreatitis This indirect sign of enlargement of the pancreas, now commonly described in text books, has often been used as a basis for the diagnosis (Frimann Dahl 1961,

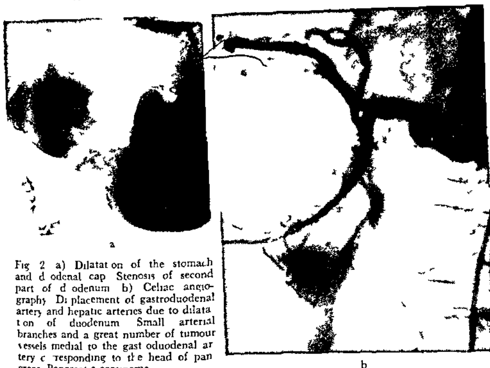
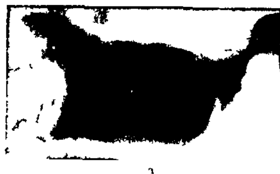


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a

Fig 3 Case 3 a) Marked dilatation of the proximal part of the duodenum caused by large intraluminal tumour b) Celiac angiography Encroachment upon gastroduodenal artery and pancreaticoduodenal arcades Tumour vessels close to proximal and distal parts of gastroduodenal artery Pancreatic carcinoma



b

Case reports

Case 1 Male aged 55 with loss of appetite and weight for a year A barium meal disclosed irregular ulceration with surrounding swelling of the mucosa of the first part of the duodenum (Fig 1a) The second part of the duodenum was normal The lesion was thought to represent a chronic ulcer or ulcerating duodenal carcinoma Combined celiac and superior mesenteric angiography (Fig 1b) revealed encroachment upon the proximal part of the gastroduodenal artery and pancreaticoduodenal arcades which were displaced *tumour vessels were evident in the head of the pancreas* The angiographic findings suggested carcinoma of the head of the pancreas and this was confirmed at operation and by pathology

Case 2 Male aged 70 with abdominal pain for six months A barium meal had demonstrated delayed gastric emptying and dilatation of the duodenal cap and second part of the duodenum, with an irregular area of stenosis in the latter (Fig 2a) He was admitted with a diagnosis of carcinoma of the duodenum Celiac angiography (Fig 2b) disclosed displacement inwards of the gastroduodenal artery and upwards of the hepatic arteries by dilatation of the duodenum The duodenal arteries from the gastroduodenal artery were stretched Medial to the gastroduodenal artery a large number of tumour vessels and infiltrated small arterial branches corresponded to the head of the pancreas The diagnosis of carcinoma of the pancreas was confirmed at operation and by pathology (the growth was highly differentiated)

Case 3 Male aged 73 with diffuse abdominal pain of one year's duration A large pyloric ulcer had been discovered in a barium meal examination A review of the films from this examination suggested dilatation of the stomach and the duodenal cap caused by obstruction repeat examination revealed practically complete obstruction by an intraluminal tumour *in the first* part of the duodenum (Fig 3a) The diagnosis of carcinoma of the



Fig 4 Case 4 a) Dilatation of proximal part of duodenum and irregular stenosis 3 cm in length distally b) Celiac and superior mesenteric angiography Infiltration of gastroduodenal artery pancreaticoduodenal arcades and proximally in some branches to the right of the superior mesenteric artery Tumour vessels corresponding to enlarged head of the pancreas Carcinoma of the pancreas

duodenum was made Celiac angiography (Fig 3b) indicated encroachment upon the proximal part of the gastroduodenal artery and its pancreaticoduodenal branches Displacement of the lower pancreaticoduodenal arcade distally with tumour vessels corresponded to a large mass in the head of the pancreas Laparotomy confirmed the diagnosis of carcinoma of the pancreas and metastases were found in the liver this was confirmed by pathology (growth of low differentiation)

Case 4 Male aged 44 with slight gastro-intestinal discomfort for several years A barium meal examination disclosed a duodenal ulcer Cholecystography revealed stones in the gallbladder Conservative ulcer treatment was given for some time and the repeat roentgen examination of the stomach indicated that the duodenal ulcer had healed but slight deformity of the duodenal cap persisted Dilatation of the whole of the duodenum with an area of irregular stenosis about 3 cm in length was evident The appearances suggested duodenal carcinoma (Fig 4a) Combined celiac and superior mesenteric angiography (Fig 4b) disclosed encroachment upon the gastroduodenal artery all branches in the pancreaticoduodenal arcades and some proximal branches from the left of the superior mesenteric artery The diagnosis of carcinoma of the pancreas was confirmed at operation Pathology of hepatic metastasis indicated that the growth was an adenocarcinoma

Case 5 Male aged 72 with marked loss of weight A barium meal examination revealed stenosis with irregular ulceration 3 cm × 2 cm in size probably carcinoma in the distal parts of the duodenum (Fig 5a) Combined celiac and superior mesenteric angiography (Fig 5b)

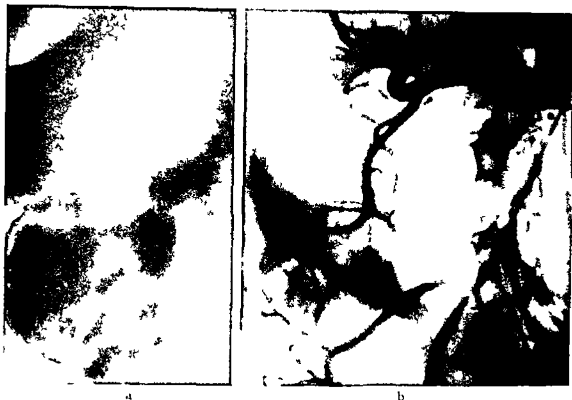


Fig. 5. Case 5. a) Stenosis and 3 cm × 2 cm area of ulceration in distal third of duodenum. b) Combined celiac and superior mesenteric angiography. Encroachment upon dorsal pancreatic artery, pancreaticoduodenal arcades and proximal part of superior mesenteric artery. A few tumour vessels in enlarged head of pancreas. Carcinoma of the pancreas.

presented evidence of encroachment upon the dorsal pancreatic artery, arcade arteries and the proximal part of the superior mesenteric artery. A few tumour vessels lay close to the dorsal pancreatic artery and in the enlarged head of the pancreas. The appearances suggested carcinoma of the pancreas. This was confirmed at operation at which carcinomatosis of the peritoneum was evident. Pathology indicated ulceration and necrosis of the distal parts of the duodenum with a tumour growing into the head of the pancreas. Microscopy disclosed an adenocarcinoma of a type more like a primary carcinoma of the pancreas than a primary duodenal carcinoma.

Case 6. Male aged 64 with loss of weight and slight jaundice. A barium meal disclosed irregular ulceration measuring 4 cm × 2 cm, probably primary duodenal carcinoma in the second part of the duodenum (Fig. 6a). Combined celiac and superior mesenteric angiography (Fig. 6b) revealed that the gastroduodenal artery together with the artery to the left hepatic lobe arose from the celiac artery with the main vascularization of the liver from the superior mesenteric artery. The left hepatic artery in its first part was displaced upwards and the gastroduodenal artery slightly stretched. Medial to the gastroduodenal artery the arterial branches were irregular and tumour vessels were evident. Operation disclosed that a tumour measuring 5 cm × 5 cm in the head of the pancreas extended into the duodenum where ulceration was present. It was impossible to decide whether the

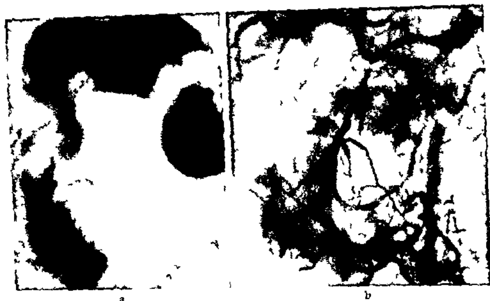


Fig 6 Case 6 a) Irregular ulceration in the peripapillary part of the duodenum b) Combined celiac and superior mesenteric angiography Irregular arteries medial to the gastroduodenal artery corresponding to the head of the pancreas with numerous tumour vessels Carcinoma of the pancreas

changes were due to a duodenal ulcer with edema in the head of *the pancreas or constituted* a carcinoma of the pancreas ulcerating into the duodenum Biopsy Carcinoma (adenocarcinoma Resection

Case 7 Male aged 68 operated on for carcinoma of the colon 20 years previously with a two month history of slight pain in the abdomen *diarrhea and loss* of weight Barium meal examination presented evidence of a large lobulated tumour in the second part of the duodenum (Fig 7a) Celiac angiography *(Fig 7b)* revealed infiltration of the gastroduodenal artery branches of the dorsal pancreatic *artery and pancreaticoduodenal* arcades Numerous tumour vessels with other vascular changes characteristic of a large pancreatic carcinoma were present Operation with resection of tumour *that* proved to be a carcinoma of the pancreas

Discussion

The seven cases presented had roentgenographic changes different from those usually encountered *in carcinoma* of the pancreas Irregular ulceration was present in the apex part of the duodenal cap *in* Case 1 The diagnosis of duodenal ulcer was made originally but as conservative treatment had no effect on the size of the ulcer *a diagnosis* of primary duodenal carcinoma was substituted

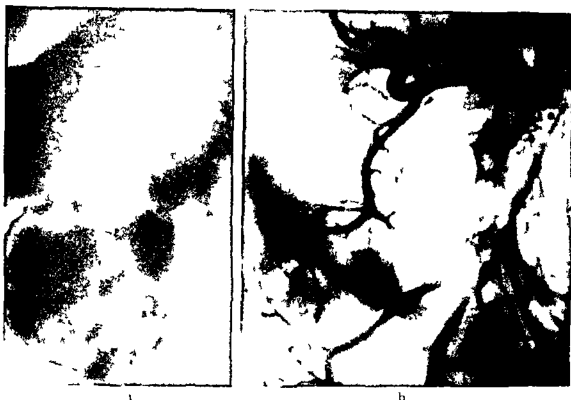


Fig. 5. Case 5. a) Stenosis and 3 cm × 2 cm area of ulceration in distal third of duodenum. b) Combined celiac and superior mesenteric angiography. Encroachment upon dorsal pancreatic artery, pancreaticoduodenal arcades and proximal part of superior mesenteric artery. A few tumour vessels in enlarged head of pancreas. Carcinoma of the pancreas.

presented evidence of encroachment upon the dorsal pancreatic artery, arcade arteries and the proximal part of the superior mesenteric artery. A few tumour vessels lay close to the dorsal pancreatic artery and in the enlarged head of the pancreas. The appearances suggested carcinoma of the pancreas. This was confirmed at operation at which carcinomatosis of the peritoneum was evident. Pathology indicated ulceration and necrosis of the distal parts of the duodenum with a tumour growing into the head of the pancreas. Microscopy disclosed an adenocarcinoma of a type more like a primary carcinoma of the pancreas than a primary duodenal carcinoma.

Case 6. Male aged 64 with loss of weight and slight jaundice. A barium meal disclosed irregular ulceration measuring 4 cm × 2 cm, probably primary duodenal carcinoma in the second part of the duodenum (Fig. 6a). Combined celiac and superior mesenteric angiography (Fig. 6b) revealed that the gastroduodenal artery together with the artery to the left hepatic lobe arose from the celiac artery with the main vascularization of the liver from the superior mesenteric artery. The left hepatic artery in its first part was displaced upwards and the gastroduodenal artery slightly stretched. Medial to the gastroduodenal artery the arterial branches were irregular and tumour vessels were evident. Operation disclosed that a tumour measuring 5 cm × 5 cm in the head of the pancreas extended into the duodenum where ulceration was present. It was impossible to decide whether the

Angiographic changes in primary duodenal carcinoma are characterized by an involvement of the duodenal branches of the gastroduodenal artery with the latter merely displaced medially If the tumour encroaches upon the pancreas peripheral arterial branches within this organ may be involved The present cases of carcinoma of the pancreas had changes in feeding arteries such as the dorsal pancreatic artery, gastroduodenal artery and the proximal part of the superior mesenteric artery Such changes were evident at celiac and superior mesenteric angiography They were never present in primary duodenal carcinoma The angiographic changes were typical of carcinoma of the pancreas in Case 5 in which some doubt was expressed in the pathology findings Angiography may therefore be used as a support for a diagnosis of such a condition This case is to a certain extent comparable to those discussed in the earlier paper (OLSSON 1971) in four cases of which the same doubt arose the angiographic changes however supported the diagnosis of primary duodenal carcinoma

Angiography in carcinoma of the pancreas involving the duodenum but suggesting primary duodenal carcinoma thus appears to constitute the means of arriving at the correct diagnosis The clarification may well be important to the surgical approach

SUMMARY

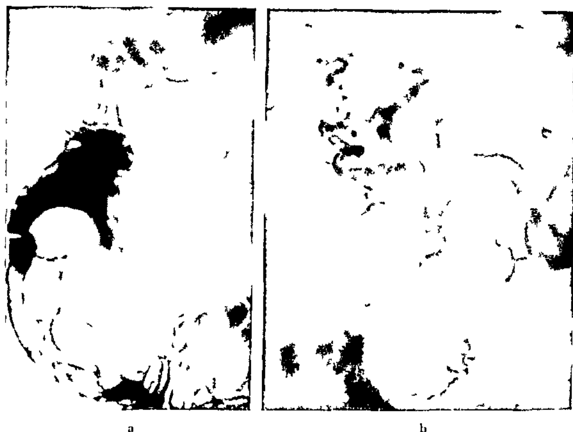
The ability of angiography to demonstrate vascular changes typical of carcinoma of the pancreas is proved in seven illustrative cases Its particular value lies in distinguishing between for instance primary duodenal carcinoma and carcinoma of the pancreas often impossible with a barium meal examination

ZUSAMMENFASSUNG

Die Anwendbarkeit der Angiographie vaskulare Veranderungen nachzuweisen die typisch fur das Carcinom des Pankreas sind wurde in sieben illustrativen Fallen nachgewiesen Deren besonderer Wert liegt in der Unterscheidungsmoglichkeit beispielsweise eines primaren Carcinoms des Duodenum und einem Carcinom des Pankreas was mit einer Bariummahlzeit Untersuchung oft unmoglich ist

RÉSUMÉ

La présentation de sept cas montre que l'angiographie permet de mettre en evidence des modifications vasculaires typiques du cancer du pancréas Son interet particulier réside dans le diagnostic differentiel entre par exemple le cancer primitif du duodenum et le cancer du pancréas diagnostic qui est souvent impossible par le repas baryte



a b

Fig. 7. Case 7. a) Large intraluminal tumour in second part of duodenum. b) Celiac angiography. Encroachment upon gastroduodenal artery and its branches and in those from the dorsal pancreatic artery. Large number of tumour vessels in head of pancreas. Carcinoma of *the pancreas.*

Case 2 had stenosis in the second part of the duodenum, Case 4 displayed irregular stenosis more distally, stenosis with a large area of ulceration in about the same region was present in Case 5 and a large ulcer was evident in the second part of the duodenum in Case 6. Cases 3 and 7 had a large intraluminal mass, in the former completely blocking the passage through the duodenum. Cases 1, 2, 4, 5 and 6 directly correspond to the same case numbers as in the paper on primary duodenal carcinoma (OLSSON 1971).

The probable diagnosis in the barium meal examinations of the cases was primary duodenal carcinoma. A comparison between a series of films of primary duodenal carcinoma and carcinoma of of the pancreas involving the duodenum thus demonstrates that it is not possible to differentiate between these two distinctly different lesions. Differentiation is obviously essential and it is here that angiography has proved of such value.

Angiographic changes in primary duodenal carcinoma are characterized by an involvement of the duodenal branches of the gastroduodenal artery with the latter merely displaced medially. If the tumour encroaches upon the pancreas peripheral arterial branches within this organ may be involved. The present cases of carcinoma of the pancreas had changes in feeding arteries such as the dorsal pancreatic artery, gastroduodenal artery and the proximal part of the superior mesenteric artery. Such changes were evident at celiac and superior mesenteric angiography. They were never present in primary duodenal carcinoma. The angiographic changes were typical of carcinoma of the pancreas in Case 5 in which some doubt was expressed in the pathology findings. Angiography may therefore be used as a support for a diagnosis of such a condition. This case is to a certain extent comparable to those discussed in the earlier paper (OLSSON 1971) in four cases of which the same doubt arose, the angiographic changes however supported the diagnosis of primary duodenal carcinoma.

Angiography in carcinoma of the pancreas involving the duodenum but suggesting primary duodenal carcinoma thus appears to constitute the means of arriving at the correct diagnosis. The clarification may well be important to the surgical approach.

SUMMARY

The ability of angiography to demonstrate vascular changes typical of carcinoma of the pancreas is proved in seven illustrative cases. Its particular value lies in distinguishing between for instance primary duodenal carcinoma and carcinoma of the pancreas often impossible with a barium meal examination.

ZUSAMMENFASSUNG

Die Anwendbarkeit der Angiographie vaskulare Veranderungen nachzuweisen die typisch fur das Carcinom des Pankreas sind wurde in sieben illustrativen Fallen nachgewiesen. Der besonderer Wert liegt in der Unterscheidungsmoglichkeit beispielsweise eines primaren Carcinoms des Duodenum und einem Carcinom des Pankreas was mit einer Bariummahlzeit Untersuchung oft unmoglich ist.

RÉSUMÉ

La presentation de sept cas montre que l'angiographie permet de mettre en evidence des modifications vasculaires typiques du cancer du pancréas. Son interet particulier reside dans le diagnostic differentiel entre par exemple le cancer primitif du duodenum et le cancer du pancréas diagnostic qui est souvent impossible par le repas baryté.

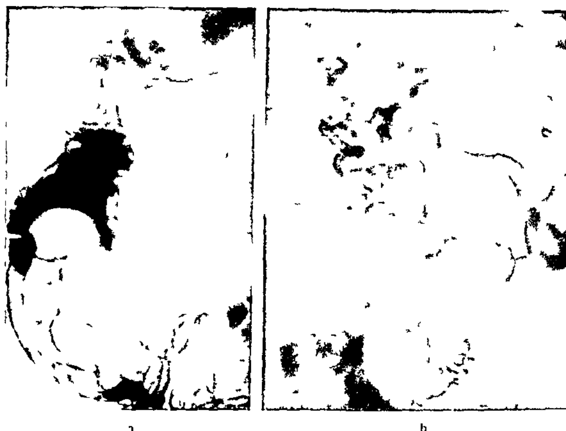


Fig 7 Case 7 a) Large intraluminal tumour in second part of duodenum b) Celiac angiography Encroachment upon gastroduodenal artery and its branches and in those from the dorsal pancreatic artery Large number of tumour vessels in head of pancreas Carcinoma of the pancreas

Case 2 had stenosis in the second part of the duodenum, Case 4 displayed irregular stenosis more distally, stenosis with a large area of ulceration in about the same region was present in Case 5 and a large ulcer was evident in the second part of the duodenum in Case 6 Cases 3 and 7 had a large intraluminal mass, in the former completely blocking the passage through the duodenum Cases 1, 2, 4, 5 and 6 directly correspond to the same case numbers as in the paper on primary duodenal carcinoma (OLSSON 1971)

The probable diagnosis in the barium meal examinations of the cases was primary duodenal carcinoma A comparison between a series of films of primary duodenal carcinoma and carcinoma of of the pancreas involving the duodenum thus demonstrates that it is not possible to differentiate between these two distinctly different lesions Differentiation is obviously essential and it is here that angiography has proved of such value

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GASTRIC ULCERATION REVEALED ONLY BY GASTROPHOTOGRAPHY

by

NILS GABRIELSSON

The accuracy of the diagnosis of gastric ulceration by conventional roentgenography is estimated at between 90 and 95 per cent (KEUTNER 1939, HALEY & SENOTH 1951) It is considerably less in gastroenterostomy cases and has been reported as low as 50 per cent (WYCHULIS et coll 1966) Ulceration may also be diagnosed by gastroscopy and gastrophotography but these techniques are usually regarded as supplementary and not alternatives to roengen examination (SCHINDLER 1950) Gastroscopy is said to be indicated if a chronic stomach disease is suspected or if complete examination including roentgen has revealed only doubtful findings or no pathology at all (SCHINDLER 1950) Roentgen examination supplemented by gastrophotography produces better results than either method by itself (PERNA et coll 1965 MORRISSEY et coll 1965)

The present investigation deals with a series of cases in which roentgen examination of the stomach was supplemented by gastrophotography and in which ulceration was diagnosed only by the latter method The aim was to investigate the causes of the diagnostic failures and to estimate whether more ulcers would have been diagnosed with an improved roentgenographic technique

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REFERENCES

Frimann-Dahl, J.: Radiology in tumors of the pancreas. Clin. Radiol. 12 (1961), 73.

Frostberg, N.: A characteristic duodenal deformity in cases of different kinds of peri-vaterial enlargement of the pancreas. Acta radiol. 19 (1938), 164.

Larsen, K. and Pedersen, A.: Roentgenologic findings in the stomach and duodenum in cancer of the pancreas. Acta radiol. 45 (1956), 159.

Lunderquist, A.: Angiography in carcinoma of the pancreas. Acta radiol. (1965) Suppl. No. 235.

Olsson, O.: Angiographie bei Pankreastumoren. Radiologe 5 (1965), 281.

— Angiography in tumors of the pancreas. *In*: Progress in radiology, p. 420. ICS No. 105. Excerpta Medica Foundation, Amsterdam 1965.

— Angiography in duodenal cancer. *In*: Proceedings of the Scandinavian Society of Medical Radiology Congress, p. 107 (abstract). Copenhagen 1968.

— Angiography in tumours of the pancreas. *In*: Modern trends in diagnostic radiology. Edited by J. W. McLaren. Butterworths, London 1970.

— Angiography in duodenal carcinoma. Acta radiol. Diagnosis 11 (1971), 177.

— Angiography in the diagnosis of duodenal lesions. II. Benign tumours, ulceration and inflammatory and vascular lesions. To be published in Acta radiol. Diagnosis.

Perez, C., Powers, W., Holtz, S. and Spjut, H.: Roentgenologic-pathologic correlation of resectable carcinoma of the pancreaticoduodenal region. Amer. J. Roentgenol. 94 (1965), 438.

Russell, W. and Marculis, A.: Impression on the duodenal loop resulting from tumor of the pancreas. Amer. J. Roentgenol. 94 (1965), 449.

Salik, J.: Pancreatic carcinoma and its early roentgenologic recognition. Amer. J. Roentgenol. 86 (1961), 1.

Table 2

Type of operation location and size of ulcer at gastrophotography

Type of operation	No of cases	Ulcer in intestine	Ulcer at stoma	Ulcer just above stoma				Diameter of ulcer	
				Less curv	Great curv	Ant wall	Post wall	5 mm or under	> 5 mm
P I	5	–	1	4	–	–	—	3	2
B II	16	5	6	3	–	2	—	4	12

In 4 cases the ulcer lay just opposite the stoma

Gastrophotography was carried out with the Olympus gastrocamera models 5 and 5 A, and with the fibergastroscope models GTF and GFB Model 5 was used in 16 cases 5 A in 36 cases GTF in 3 cases and GFB in 1 case Models 5 and GTF were both employed in 3 cases and models 5 A and GFB in 1 case The various models have been described (GABRIELSSON 1966 HARA et coll 1967 OSHIMA 1966 OSHIMA & ASHIZAWA 1967 WILLIAMS et coll 1968) The technique of gastrophotography favoured by the author differs from the conventional one in that the camera is positioned with the help of TV fluoroscopy (GIDLUND 1965 GABRIELSSON 1966 1967 1970)

The stomach is divided into four parts by longitudinal section for describing the location of ulceration These are called the lesser or greater curvature part and the anterior or posterior wall part the wall is thus divided into four longitudinal strips like a banana skin These longitudinal sections are furthermore divided into three parts by transverse cuts These parts are the prepyloric and antral part the angulus part consisting of the body a third of the distance between the cardia and angulus and the proximal region of the body and fornix part

No complications occurred in the series

Differential diagnosis The roentgen diagnosis of ulceration depends on the demonstration of a niche or crater When a chronic gastric ulcer remains hidden this is considered to be due to the following factors (ZBORALSKE 1967) (1) the ulcer may be shallow (2) the ulcer may be filled with residues of mucus blood food or necrotic tissue or (3) its margins may be oedematous and occluded (4) the anatomy may preclude satisfactory roentgenographic detail and (5) a small ulcer may be obscured by large rugal folds Conversely, crater like patterns may be produced by barium trapped between gastric folds Diverticula may be difficult to differentiate from ulcers if no mucosal folds are seen in them

Table I

Location and size of ulcer at gastrophotography in nonoperated cases

Location of ulcer	No of cases	Lesser curv	Greater curv	Ant wall	Post wall	Diameter of ulcer	
						5 mm or under	> 5 mm
Prepyloric and antral part	10	6	2	2	—	4	6
Angulus and distal corp part	13	13	—	—	—	5	8
Prox corp and fornix part	16	6	4	—	6	4	12

The aim also was to determine whether ulceration is more easily missed in one part of the stomach than in the other parts on roentgen examination

Material The series comprised 60 cases in which a gastric ulcer was diagnosed by gastrophotography but unrevealed on conventional barium examination, it was collected from a total of 600 cases examined between 1966 and 1969 The gastrophotographic diagnosis was definite and the ulcer was evident in films exposed from different directions Only 8 cases were operated upon and confirmation was consequently absent in the others The series consisted of 22 females and 38 males aged from 24 to 79 with an average of 56 years Operation had been performed according to Billroth I in 5 cases and Billroth II in 16 cases The roentgen examinations were always performed before gastrophotography, the interval between the examinations being less than 1 week in 27 cases, 1 to 2 weeks in 14 cases 2 to 3 weeks in 10 cases and more than 3 weeks in 9 cases The symptoms had usually improved when gastrophotography was performed, objective deterioration was not evident in any case

Methods The roentgen examinations were performed and interpreted as routine examinations by various radiologists of the department, including the author The examinations were performed in the erect prone and supine positions and included cushion compression, air swallowed during the barium meal was used for a simple double contrast examination in the supine position Gastroenterostomies were always examined erect and laterally TV fluoroscopy was employed only occasionally Full size films were the rule

Table 4

Location of ulcers not distinguishable in roentgen films and the frequency of probable causes of failure

Location of ulcer	No of cases	Ulcer obscured by large folds	Ulcer too small	Ulcer too shallow	Ulcer not properly projected	Ulcer filled with clot
Prepyloric and antral part	6	1	1	4	—	—
Angulus and dist corpus part	8	3	1	2	2	—
Fornix and prox corpus part	11	4	—	1	4*	2
Resected stomach ad modum B I	5	3	2	—	—	—
Resected stomach ad modum B II	15	12	3	—	—	—
Total	45	23	7	7	6	2

In 2 cases ulceration of lesser curvature was concealed by the bulging fornix of a cascade stomach

Ulcerations in malignant tumours were confirmed on operation in 3 cases The malignant character of the ulcer was revealed by gastrophotography in 2 cases and considered probable in 1 case Rigidity of the gastric wall at conventional roentgen examination suggested malignancy in 2 cases although no ulceration was evident Review of the roentgen films disclosed two of the three ulcers One very large ulcer had been erroneously interpreted as a permanent bulge of the wall The other ulcer was partly filled with clots both at gastrophotography and roentgen examination this prevented barium filling the whole crater The third malignant ulcer which was over 5 mm in diameter failed to be found on review of the films

Five ulcers of the whole series were obvious on review Ten ulcers were recognized at this same review but only because of the knowledge of its location gained from gastrophotography the appearances being atypical Without this indication it would not have been possible to differentiate the ulcer from pseudoniches between large folds

The ulcer could not be detected in the roentgen film in the remaining 45 cases even when its situation was known The probable cause in 23 of these was large gastric folds that obscured the ulcer niche or crater This diagnostic problem was most common in partially resected stomachs In 3 of 5 cases

Table 3

Location of ulcer at gastrophotography and results of review of roentgen films

Location of ulcer	No. of cases	Diagnosis confirmed on review of films	Ulcer outlined but atypical appearance prevented diagnosis	Ulcer not outlined
Prepyloric and antral part	10	2	2	6
Angulus and dist. corpus part	13	1	4	8
Fornix and prox. corpus part	16	2	3	11
Resected stomach ad modum B I	5	—	—	5
Resected stomach ad modum B II	16	—	1	15
Total	60	5	10	45

Several films must be exposed from different directions to establish a correct diagnosis by gastrophotography. Oblique illumination will demonstrate the level of the probable lesion in relationship to mucosa. Chronic peptic ulcers are usually regular and have a sharp edge (SCHINDLER 1950). Reactive phenomena such as surrounding oedema, radiating folds and semicircular shrinkage or contraction of the gastric wall are often present adjacent to the ulcer. Acute shallow ulcers are covered with fibrinous exudate and may have an irregular shape; they may be difficult to distinguish from adherent mucus covering an intact mucosa. Reddening and swelling around the ulcer usually make diagnosis possible.

Results

The results of gastrophotography and a review of roentgen examinations are summarized in Tables 1 to 5.

Gastrophotography demonstrated two ulcers in 8 cases and three ulcers in 2 cases. The ulcers were usually adjacent to each other. One of the multiple ulcers was demonstrated on roentgen examination in 4 cases, none of the ulcers was diagnosed on roentgen examination in the remaining 6 cases. An ulcer was diagnosed by gastrophotography in 2 cases with sliding hiatus hernia, the ulcer lay at the hiatus in 1 case and just below it in the other case. None of the ulcers was evident on review of the roentgen films.

Table 4

Location of ulcers not distinguishable in roentgen films and the frequency of probable causes of failure

Location of ulcer	No of cases	Ulcer obscured by large folds	Ulcer too small	Ulcer too shallow	Ulcer not properly projected	Ulcer filled with clot
Pre pyloric and antral part	6	1	1	4	—	—
Angulus and dist corpus part	8	3	1	2	2	—
Fornix and prox corpus part	11	4	—	1	4*	2
Resected stomach ad modum B I	5	3	2	—	—	—
Resected stomach ad modum B II	15	12	3	—	—	—
Total	45	23	7	7	6	2

* *In 2 cases ulceration of lesser curvature was concealed by the bulging fornix of a cascade stomach*

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operated according to B I and in 12 of 16 cases with B II gastroenterostomies the lesser curvature was markedly irregular just above the anastomosis This distortion of the mucosa in resected stomachs arises following irregular suturing of the lesser curvature (KIM & EVANS 1959) Deformity without visible ulceration was evident in 7 cases at roentgen examination at the involved site At gastrophotography the ulcers seemed to be shallow in these cases The ulcer at gastrophotography in another 7 cases was *considered too small to be detected by* roentgen examination In 5 of these cases the ulcer was located in partially resected stomachs It appears to have been confirmed in phantoms that superficial marginal ulcers cannot be demonstrated radiologically (VARGHA 1965) The patient in 4 instances had not been adequately positioned for tangential rays of the posterior wall of the corpus and fornix and the craters did not appear in the en face projection because of an unsatisfactory mucosal investigation The bulging fornix of a cascade stomach in 2 additional cases concealed the ulcer in the upper part of the lesser curvature A clot evident at gastrophotography, probably prevented barium entering the crater in 2 cases

Discussion

The interval between the roentgen examination and gastrophotography was less than 14 days in two thirds of the cases of the series An ulcer may of course have sometimes developed after the roentgen examination especially in those in which a longer time had elapsed This is however highly unlikely as deterioration in the interval was never reported

An ulcer, obvious in the films but overlooked at the time of examination by the radiologist, as occurred in 5 cases of the present investigation, was classified as due to a mistake in interpretation and not in method

Atypical roentgenographic appearances of the ulcer may be correctly interpreted only if the location of the lesion is known, as occurred in 10 cases of the present investigation The ulcer is outlined but impossible to recognize without its location being known The inadequacy of the roentgen examination depends both on its inherent limitations, which may fail to demonstrate the ulcer clearly enough, and on inadequate interpretation of atypical appearances It is improbable that an improved technique would have helped matters

Ulceration could not be detected in the roentgen films in 45 cases of the present series even when its location was known There was no sign of a niche or crater that might have suggested ulceration The most common probable cause was *large gastric folds obscuring the ulcer, apparent* in 23 cases It is difficult to improve the roentgen diagnostic accuracy in similar cases in view of the inherent limitations of the method A meticulous double contrast technique with different degrees of distension of the stomach and various positions of the



Fig 1



Fig 2

Fig 1 Ulceration of the posterior wall of the proximal part of the body of the stomach The crater is shallow and surrounded by reddened and slightly swollen mucosa In ersion position of the camera

Fig 2 A deep crater of the posterior wall of the pro imal part of th body A small clot may ha e prevented the influx of barium



Fig 3



Fig 4

Fig 3 Ulceration close to the cardia in the same ase as in fig 2 Both ulcers were on two occa ions unrevealed on roentgen examination

Fig 4 Marginal ulcer on the le ser curvati re 1 to 2 cm above the anastomosis according to B II



Fig 5



Fig 6

Fig 5 Ulc ration in the proximal part of the efferent loop in B II resection

Fig 6 Exter sive ulcerat on close to the *angulus correctly* interpreted as malignant at gastrophot gr phy Roentgen examination suggested that it was a rigid bulg of the infiltrated all

Table 5

Nonoperated cases Location of ulcer diagnosed by gastrophotography but not detected by roentgen examination as compared to location of those diagnosed by both methods between 1966 and 1969

Location of ulcer	Results of roentgen examination		Frequency of undetected ulcers
	No of cases with undetected ulcer	No of cases with diagnosed ulcer	
Fornix and prox corpus part	16	16	50
The rest of the stomach	23	103	18

Significance of difference $p < 0.001$

patient would perhaps sometimes have demonstrated the lesions (SHIRAKABE et coll 1966) The next common causes of the failing in the roentgen examinations were ulcers considered too small or too shallow at gastrophotography to be detected on roentgen examination as occurred in 14 cases of the present investigation in 2 of these the ulcer was located in the anterior wall of the prepyloric and antral part and in another 2 cases in the anterior wall just above a Billroth II stoma A careful double contrast examination in the prone position may have revealed these superficial lesions of the anterior wall Wrong positioning of the patient without tangential rays of the posterior wall of the body and fornix was the cause of the diagnostic failure in 4 cases The ulcers did not appear in an en face projection in an unsatisfactory mucosal examination The bulging fornix of a cascade stomach concealed the upper part of the lesser curvature in 2 cases More adequate compression exerted over the stomach, an improved double contrast technique or if necessary angulation of the roentgen tube should have made a proper demonstration of the lesser curvature and ulcer possible A clot in the ulcer was the probable explanation of the diagnostic inadequacy in 2 cases Gastrointestinal haemorrhage before the examinations was reported in 32 cases A clot in the ulcer at the time of roentgen examination probably helped to conceal the lesion in more than 2 cases as the roentgen examination was performed closer to the onset of bleeding than was gastrophotography

At least 11 more ulcers should have been diagnosed in the present series with a more skilful interpretation of roentgen films and a better technique of examinations With a meticulous double contrast technique further ulceration might have been revealed where the cause of the failure was considered to be large folds obscuring the lesion or where the ulcer was too small or too shallow

About two thirds of the ulcers will always remain undetected by roentgen examination due to its inherent limitations

The situation of ulcers in non operated stomachs, diagnosed by gastrophotography but undetected by roentgen examination, was compared to the location of those diagnosed by both methods during the same period of time The results are explored in Table 5 There was a higher relative frequency of ulcers, not recognized on roentgen examination, in the fornix and proximal part of the body than in the rest of the stomach The difference in frequency was highly significant ($p < 0.001$)

Conclusions

Pure errors in interpretation of roentgen films were uncommon in the present investigation (5 cases) Twice as frequently (10 cases) the diagnostic failure depended on a combination of inadequate interpretation and inherent limitations of the method The ulcer in these cases was outlined but impossible to recognize due to the atypical appearances and surrounding pseudoniches

The most likely explanation of ulcers undetected on conventional barium examination were large gastric folds obscuring the crater (23 cases) and the ulcers being too shallow (7 cases) and too small (7 cases) The lesion was not properly projected in 6 cases and in 2 cases a clot in the crater probably *prevented the influx of barium* A perfect technique of examination *including* double contrast examinations in various positions with different degrees of distension of the stomach, should have revealed those ulcers not properly projected (6 cases) and probably the lesions of the anterior wall as well (4 cases) There are reasons to believe that a small number of ulcers, obscured by large gastric folds and considered too small or shallow, should still have been demonstrable However, in about two thirds of the series the failure depended on the inherent limitations of the method, which could not be overcome

The *most common* situation of ulceration missed at roentgen examination was close to a gastroenterostomy ad modum Billroth II (16 cases) and in the fornix and proximal part of the body of the stomach (16 cases) Ulceration in the latter situations was more easily overlooked at roentgen examination than that in the other parts of the non operated stomach The difference was highly significant

Acknowledgements

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SUMMARY

A series of 60 cases with gastric ulceration not evident at conventional roentgen examination but diagnosed by gastrophotography was investigated to find the causes of the failure. The further aim was to discover whether ulceration in one part of the stomach is more easily overlooked than in other parts at roentgen examination.

ZUSAMMENFASSUNG

Eine Serie von 60 Fallen mit Ulcerationen des Magens, die nicht mit konventionellen Rontgenuntersuchungen, sondern durch Gastrophotographie diagnostiziert worden waren, wurde untersucht, um die Ursachen dieser negativen Resultate festzustellen. Ein weiteres Ziel der Untersuchung war festzustellen, ob bei Rontgenuntersuchungen Ulcerationen in einem Teil des Magens leichter ubersehen werden als in anderen Teilen.

RÉSUMÉ

Afin de decouvrir les causes de ses echecs, l'auteur a etudie une serie de 60 cas d'ulcérations gastriques qui n'avaient pas éte mises en evidence par l'examen radiologique ordinaire et qui avaient ete diagnostiquees par gastro-photographie. Un autre but de cette etude etait de determiner si l'ulceration gastrique échappe plus facilement a l'examen radiologique dans certaines parties de l'estomac que dans d'autres.

REFERENCES

GABRIELSSON N. Fargfotografering med gastrokamera som komplement till rontgenundersokning av ventrikeln. (In Swedish.) Nord Med 75 (1966) 739.
— Fargfotografisk undersokning vid magblodning med normalt rontgenfynd. (In Swedish.) Lakartidn 64 (1967) 2465.
— Gastrophotograhy in upper gastrointestinal haemorrhage without roentgenographically demonstrable source of bleeding. Endoscopy 2 (1970) 174.
GIDLUND A. Personal communication (1965).
HALEY T. J. and SENOTH W. M. The diagnostic accuracy of the roentgen examination in disease of upper gastrointestinal tract. Radiology 56 (1951) 416.
HARA Y., TOBITA Y., TSUNODA H. and SUGIYAMA K. Intragastric photography. Gastrocamera with fiberscope. Arch Surg 94 (1967) 337.
KEUTNER H. Die heutige Treffsicherheit der Rontgendiagnostik bei Erkrankungen des Magens und Zwolffingerdarmes. Fortschr Rotgenstr 60 (1939) 421.
KIMS Y. and EVANS J. A. The roentgen appearence of the stomach and duodenum following the Billroth I gastric resection. Amer J Roentgenol 81 (1959) 576.
MORRISSEY J. F., HONDA T., HARA Y. et coll. The use of the gastrocamera for the diagnosis of gastric ulcer. Gastroenterology 48 (1965) 711.
OSHIMA H. Die Gastrocamera, ein neues photographisches Untersuchungsgerat fur die Magenhohle. Gastroenterologia 105 (1966) 115.
— und ASHIZAWA S. Gastrocamera Typ 5 A Z. Gastroenterologie 5 (1967) 142.
PERNA G., HONDA T. and MORRISSEY Y. F. et coll. Gastrocamera photography. Arch intern Med 116 (1965) 434.

SCHINDLER R Gastroscopy The endoscopic study of gastric pathology Hafner Publish Co Inc , New York 1950 Second edition 1966

SHIRAKABE H et coll Atlas of X ray diagnosis of early gastric cancer J B Lippincott, Philadelphia 1966

VARGHA J Phantomversuche am operierten Magen von Hunden Fortschr Röntgenstr 103 (1965) 301

WILLIAMS G TRUELOVE S C GEAR M W L et coll Gastroscopy with biopsy and cytological sampling under direct vision Brit med J 1968 I p 535

WYCHULIS A R PRIESTLEY J T and FOULK W T et coll A study of 360 patients with gastrojejunal ulceration Surg Gynec Obst 122 (1966) 89

ZBORALSKE F F Gastric ulcer *In* Alimentary tract roentgenology Volume I p 475 Edited by A R Margulis and H J Burhenne Mosby Co , St Louis 1967

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SIZE OF THE NORMAL PAROTID GLAND

by

SUNE ERICSON

Earlier investigations have indicated that a large variation in the size and duct system of the parotid gland is normal and that the variation in healthy subjects is probably due mainly to constitutional factors (HETZAR 1942, HETTWER & FOLSOM 1968, PFEIFFER 1968, ERICSON 1968, 1970, SCHULZ 1969). A weak correlation between the size of the gland and sex, menopause and age have been recorded although in view of the large biologic variation this is probably of little significance (ERICSON 1970). JANCZUK & JEDRZEJEWSKA (1966) stated however that atrophy of the parotid gland may occur without signs of disease in patients over 65.

The variation in the size of the parotid gland in healthy subjects is in practice so large that it is often difficult to judge whether a gland is atrophied or hypertrophied, since the latter glands, if originally small, may still be within the normal range of variation. Likewise, atrophic changes in originally large glands may be concealed unless the size is followed continuously. A high left—right correlation for the parotid gland in a subject however exists (ERICSON 1968, 1970). This affords a means of detecting or verifying atrophic or hypertrophic changes when only one of the glands is affected or involved to a greater extent than the other, or when the course of a pathologic process in a parotid gland is to be followed. The object of the present investigation

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SCHINDLER R. Gastroscopy. The endoscopic study of gastric pathology. Hafner Publish. Co. Inc. New York 1950. Second edition 1966.

SHIRAKABE H. et coll. Atlas of X-ray diagnosis of early gastric cancer. J. B. Lippincott. Philadelphia 1966.

VARGHA J. Phantomversuche am operierten Magen von Hunden. Fortschr. Röntgenstr. 103 (1965) 301.

WILLIAMS C., [illegible] S. C., GEAR M. W. L. et coll. Gastroscopy with biopsy and cytological sampling under direct vision. Brit. med. J. 1968 I p. 535.

WYCHULIS A. R., PRIESTLEY J. T. and FOULK W. T. et coll. A study of 360 patients with gastrojejunal ulceration. Surg. Gynec. Obst. 122 (1966) 89.

ZBORALSKE F. F. Gastric ulcer. *In* Alimentary tract roentgenology. Volume 1 p. 475. Edited by A. R. Margulis and H. J. Burhenne. Mosby Co. St. Louis 1967.

Table 1

The mean (x), standard deviation (SD) and range for the lateral and frontal sialographic projections of the parotid gland area (in cm²); n is the number of observations

Area	Lateral projection				Frontal projection			
	n	x	SD	Range	n	x	SD	Range
Right gland	92	15.5	2.7	9.9–21.0	81	16.2	2.5	10.1–21.8
Left gland	92	15.6	2.9	5.9–21.0	81	15.9	2.9	4.2–20.7

projection at an angle of 78° to the sagittal plane and in the a.p. projection perpendicular to the plane of the film and tangential to the ascending ramus of the mandible; during the exposures the chin was gently pressed. The FFD was 70 cm. The contrast medium, Urografin 60 %, was injected slowly and interrupted when the subject experienced moderate pain in the cheek just in front of the ear. A further 0.1 to 0.3 ml of the contrast medium was then injected and a roentgenogram obtained immediately with a precision apparatus for skull radiography (Elema Schonander CRT 4). The amount of contrast medium injected never exceeded 1.2 ml.

The size of the gland was determined planimetrically by determining the area of the projected gland in the sialogram (ERICSON 1968): the parotid glands were outlined in pencil (Fig. 1) and the enclosed area measured with an Aristo planimeter No. 1130.

The precision and accuracy of the method have been examined previously in cadavers by injections into and measurements of the gland in situ in the sialograms and after extirpation (ERICSON & HEDIN 1970). The correlation between the parotid area in the sialogram and in situ in the cadaver was extremely high with r = 0.97.

The relationships between the lateral area of the parotid gland as measured in situ in the sialogram and the total volume of the gland determined after extirpation were also close. The correlation coefficients were r = 0.95 and 0.96 respectively. It follows from the high coefficients that the area of the lateral projection of the parotid gland is proportional to the volume and affords a useful indication of the size of the gland.

Errors of the method incurred in the outlining, calculation and orientation of the subject in the path of the beam were all negligible compared with the inter-subject variation in parotid size. The standard deviation for a single determination of the area of a gland in the lateral projection was 0.28 cm²; the value for the frontal projection was approximately the same.

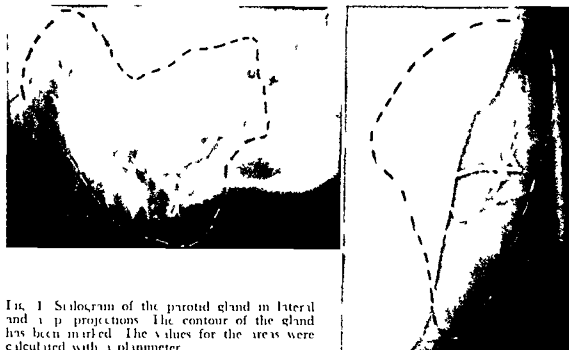


Fig. 1. Sialogram of the parotid gland in lateral and a.-p. projections. The contour of the gland has been marked. The values for the areas were calculated with a planimeter.

was to determine the smallest right–left difference in parotid gland size that may indicate abnormal conditions in at least one of the glands.

Material. This consisted of 92 healthy subjects, 61 women and 31 men, chosen at random within certain age groups from the clientele of the School of Dentistry. The ages ranged from 26 to 64 years for the women, with a mean of 49.8, and from 26 to 64 years for the men, with a mean of 48.8. The general health was checked by physical and laboratory examinations. There was no evidence of diseases that might have involved the salivary glands. Detailed accounts of the material and the methods of investigation have been given in this journal and elsewhere, and to which the reader is referred (Ericson & Jacobsson 1968, Ericson 1968, 1970).

Bilateral sialograms in lateral projection were always obtained, i.e. in 184 glands in all (see below). Frontal sialograms were taken of 162 glands; in 11 subjects such films were omitted for technical reasons or because of painful swelling following the preceding lateral sialogram.

Method. The sialographic examination of the right and left parotid glands was conducted by the method described and analyzed by Ericson (1968, 1970) and Ericson & Hedin (1970), in which the errors of the method are also considered. The method was briefly as follows. The sialograms were obtained with the central ray directed at the midpoint of the gland — in the lateral

Table 2

Mean right—left differences (absolute value d), standard deviation of the mean, and range of the differences for the lateral and frontal sialographic projection of the parotid gland area (in cm²). n is the number of observations

Area	Lateral projection				Frontal projection			
	n	d	SD	Range	n	d	SD	Range
Difference right—left	92	0.89	0.92	0—4.6*	81	1.03	1.43	0—10.0

* Except for the pair with the greatest difference, when the range was 0—4.8

ticular subject exist (Table 2). From this the greatest right—left difference that may be regarded as normal with a 97.5 per cent probability was determined by applying the 2 sigma rule. This difference was 2.7 cm² for the lateral and 3.7 cm² for the frontal projection. These values were exceeded in the lateral and frontal projections in 2 and 4 subjects respectively. All but one of these pairs were slightly smaller than the mean; one gland of the exceptional pair was extremely small and the other was small but within the normal range of variation (see ERICSON 1968, p. 48). Figs 4 and 5 indicate that this gland differed greatly from the mean and should be regarded as being in all probability anomalous or pathologically diminished, though this inference is unsupported by the history or the clinical examination.

Discussion

Earlier investigations on cadavers with healthy salivary glands have disclosed that the size of parotid glands in situ may be reproduced to a high level of accuracy by a combination of sialography and planimetry, and that the planimetric determination of the gland in the sialogram may also be used for calculating its volume (ERICSON & HEDIN 1970). ERICSON (1970) concluded that a difference in the projected area not only indicated a deviation in the extent but also a relative difference in the total volume of the gland. This arose from the high correlation coefficients between the area of the parotid gland — as projected in frontal as well as lateral sialograms — and the total volume.

The reproducibility, though high, would presumably be somewhat lower for a clinical than an autopsy investigation because the sialographic technique cannot be so consistently standardized in the former as in the latter. Comparisons between changes in the small parotid ducts in clinical subjects observed in

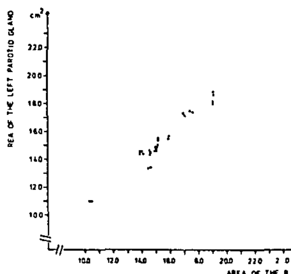


Fig. 2. Relation between the extent of the right and left parotid glands: lateral projections. Each point relates to one pair of glands.

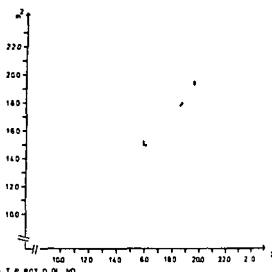


Fig. 3. Relation between the extent of the right and left parotid glands: frontal projections. Each point relates to one pair of glands.

Results

The mean ($\bar{x}$), the standard deviation of the mean (SD) and the range for the projected area of the parotid gland (in square centimetres) in lateral and frontal sialograms, are given in Table 1. The means for the areas of the right and left glands for the two projections were in close agreement. The inter-subject variation in area was extremely large, however. The coefficient r for the right—left correlation proved to be 0.90*** for the lateral projection and 0.78** for the frontal (ERICSON 1970). The right—left correlation is illustrated in Figs 2 and 3.

The right—left difference in area was calculated for each subject in the sialograms for the two projections and the means of the absolute difference ($\bar{d}$), the standard deviation (SD) and the range were determined. The mean right—left difference was about 0.9 to 1.0 cm², with a standard deviation of the same order (Table 2).

The right—left difference in the projected area of the glands for both projections was about normally distributed about the mean (Figs 4 and 5). The deviations from the mean differences also did not vary with the size of the gland, which means that the right—left difference was relatively less for the large than for the small glands.

The standard deviation of the mean difference (absolute value) was calculated to ascertain whether a significant right—left difference for a pair

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Mean right—left differences (absolute value d) standard deviation of the mean and range of the differences for the lateral and frontal sialographic projection of the parotid gland area (in cm²) n is the number of observations

Area	Lateral projection				Frontal projection			
	n	d	SD	Range	n	d	SD	Range
Difference right—left	97	0.89	0.92	0—4.6	81	1.09	1.49	0—10.0

Except for the pair with the greatest difference when the range was 0—4.8

ticular subject exists (Table 2) From this the greatest right—left difference *that may be regarded as normal* with a 97.5 per cent probability was determined by applying the 2 sigma rule This difference was 2.7 cm² for the lateral and 3.7 cm for the frontal projection These values were exceeded in the lateral and frontal projections in 2 and 4 subjects respectively All but one of these pairs were slightly smaller than the mean one gland of the exceptional pair was extremely small and the other was small but within the normal range of variation (see ERICSON 1968 p 48) Figs 4 and 5 indicate that this gland differed greatly from the mean and should be regarded as being in all probability anomalous or pathologically diminished though this inference is unsupported by the history or the clinical examination

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Earlier investigations on cadavers with healthy salivary glands have disclosed that the size of parotid glands in situ may be reproduced to a high level of accuracy by a combination of sialography and planimetry and that the planimetric determination of the gland in the sialogram may also be used for calculating its volume (ERICSON & HEDIN 1970) ERICSON (1970) concluded that a difference in the projected area not only indicated a deviation in the extent but also a relative difference in the total volume of the gland This arose from the high correlation coefficients between the area of the parotid gland — as projected in frontal as well as lateral sialograms — and the total volume

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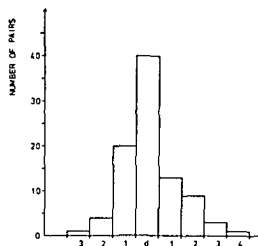


Fig. 4. Distribution of the right—left difference in gland size (in cm²): lateral projections.

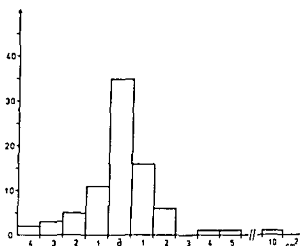


Fig. 5. Distribution of the right—left difference in gland size (in cm²): frontal projections.

sialograms and confirmed by biopsy have indicated that the sialographic method faithfully reproduces the salivary ducts and any alterations in them (Ericson 1968). A planimetric determination of the extent of the gland in the sialogram may therefore in the clinical series also be regarded as a sound basis for estimating actual differences not only in the size of the projected area but in the volume of the glands as well.

The results have disclosed a large inter-subject variation in parotid size among healthy subjects, but on the average a close right—left agreement; a considerable difference between the two glands sometimes however occurred. The results of the methodologic investigation suggest that these differences may point to true differences between the glands. It is possible however that the differences were sometimes influenced in some measure by technical factors — for example, in the lateral view a disparity in the orientation of the right and left glands with respect to the central ray because of reduced mobility of the neck and in the frontal view a masking of the medial parts of the gland by the skull.

The material included one subject judged to have a defective or pathologically small gland on one side and a normal one on the other, but since this was not supported by the history and clinical evidence the subject was not initially excluded from the material. If he had been, the standard deviation for the left—right difference would have been somewhat lower for both projections, especially the frontal, where the right—left difference in size was extreme and the standard deviation would have approached unity. The values of 2.7 and

3.7 cm obtained as the greatest right—left differences in size in the healthy subject with a 97.5 per cent probability are therefore probably maxima and have the above explanation These two values are, however, applicable in routine clinical work where the sources of errors are probably the same as those in this investigation

SUMMARY

A clinical method of assessing the size of the parotid gland by means of a combination of sialography and planimetric techniques is reported This was applied in a group of 92 normal subjects to determine how the size of the parotid glands varies An estimation was made of the greatest difference between the glands that may be accepted as normal

ZUSAMMENFASSUNG

Eine klinische Methode die Grosse der Parotis durch kombinierte Sialographie und Planimetrie zu erhalten wird beschrieben Diese wurde bei einer Gruppe von 92 normalen Individuen verwendet um festzustellen wie die Grosse der Parotis variiert Es wurde eine Bestimmung der grossten als normal zu betrachtenden Differenz der Parotis vorgenommen

RÉSUMÉ

Presentation d une methode clinique de determination des dimensions de la glande parotide par l association de techniques sialographique et planimetrique Cette méthode a ète appliquee dans un groupe de 92 sujets normaux pour determiner les variations de dimensions des glandes parotides Les auteurs donnent une estimation de la plus grande difference de dimensions entre les glandes parotides qui peut etre considere comme normale

REFERENCES

ÉRICSON S The parotid gland in persons with and without rheumatoid arthritis Acta radiol (1968) Suppl No 275

— The normal variation of the parotid size Acta oto laryng 70 (1970) 294

— and HEDIN M A clinical roentgenologic method for calculating the volume of the parotid gland Oral Surg 29 (1970) 536

— and JACOBSSON K A A secretory and clinical investigation of the parotid glands in patients with rheumatoid arthritis *Acta oto laryng* 66 (1968) 101

HETTWER K J and FOLSOM T C The normal sialogram Oral Surg 26 (1968) 790

HETZAR W Die Sialographie Georg Thieme Leipzig 1942

JÁNCZUK Z and JEDREZEJWSKA T Radiological investigation on parotid glands in patients with atrophic stomatitis Pol med J 5 (1966) 1215

PFEIFFER K M Die Rontgendiagnostik der Speicheldrusen und ihrer Ausfuhrungsgange Handbuch med Radiol 8 (1968) 308

SCHULZ H G Das Rontgenbild der Kopfspeicheldrusen Johann Ambrosius Barth Leipzig 1969

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APPEARANCE OF THE OSSIFICATION CENTRE IN THE PROXIMAL HUMERAL EPIPHYSIS OF NEWBORN CHILDREN

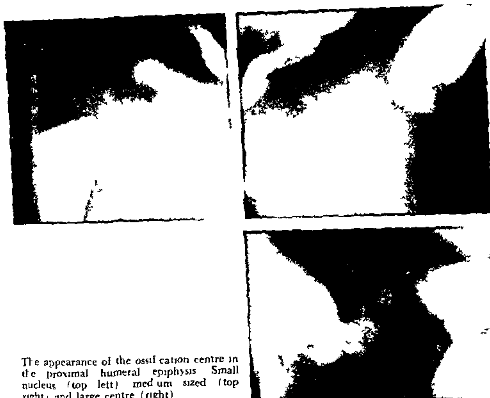
by

R LEMPERG and B LILIEQUIST

The identification of a bone nucleus in the proximal epiphysis of the humerus is of practical importance in the diagnosis of traumatic conditions, such as epiphyseal displacement or luxation of the shoulder joint, in newborns (LEMPERG & LILIEQUIST 1970) The presence of visible ossification centres at birth is known to vary with sex, weight and gestational age, and to display racial and regional differences (CHRISTIE 1949, GARN et coll 1967) An investigation of the development of the ossification centres in Swedish children was made by LIGENMARK (1946) although no special attention was paid to newborns The occurrence of a roentgenologically visible bone nucleus in the proximal epiphysis of the humerus at birth in 144 Swedish children was in the present material assessed in relation to sex, weight, length and gestational age

Material This consisted of children born alive to women admitted to the obstetric wards of this hospital in northern Sweden during the period 1965—

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The appearance of the ossification centre in the proximal humeral epiphysis Small nucleus (top left) medium sized (top right) and large centre (right)

1969 The population of the investigation area is predominantly Caucasian but with a considerable admixture of Finnish and Lapp elements (BECKMAN 1959) the present sample gave no indication of its degree of Finnish admixture

All the chest films were taken within 24 hours of birth and only those with well delinated shoulder joints were evaluated The material was not further selected except that infants with systemic diseases known to affect the skeleton were excluded The roentgenograms of 144 newborns were examined for the presence or absence of a centre in the head of the humerus positive data were analyzed in relation to sex birth weight length and gestational age (calculated in days from the last menstrual period) and were obtained from the records of the obstetric ward The composition of the roentgen films was naturally influenced by the indications for requesting them which resulted in a preponderance in the material of premature infants The main group consisted of newborn children with some form of perinatal asphyxia

Toxicosis gravidarum was evident in 14 women

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APPEARANCE OF THE OSSIFICATION CENTRE IN THE PROXIMAL HUMERAL EPIPHYSIS OF NEWBORN CHILDREN

by

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The identification of a bone nucleus in the proximal epiphysis of the humerus is of practical importance in the diagnosis of traumatic conditions, such as epiphyseal displacement or luxation of the shoulder joint, in newborns (LEMPERG & LILIEQUIST 1970). The presence of visible ossification centres at birth is known to vary with sex, weight and gestational age and to display racial and regional differences (CHRISTIE 1949, GARN et coll. 1967). An investigation of the development of the ossification centres in Swedish children was made by LEGENMARK (1946) although no special attention was paid to newborns. The occurrence of a roentgenologically visible bone nucleus in the proximal epiphysis of the humerus at birth in 144 Swedish children was in the present material assessed *in relation to sex, weight, length and gestational age*.

Material. This consisted of children born alive to women admitted to the obstetric wards of this hospital in northern Sweden during the period 1965—

Submitted for publication 19 November 1970

Results

The accompanying Figure depicts the roentgen appearances of the ossification centre in the head of the humerus It is obvious that variations in size may range from a mall to a well developed nucleus Table 1 correlates the nuclei in relation to the calculated gestational ages The shortest gestational age with a visible nucleus was 216 days in a boy a twin with a weight at birth of 1 750 g and a length of 44 5 cm The other twin, a girl had no obvious ossification centre though he was longer and heavier

Table 2 gives the weight at birth in relation to the presence of a nucleus There was a strong correlation with an almost linear relationship between these two parameters Girls had a greater tendency than boys to a higher frequency of visible nuclei but the difference was not statistically significant The lowest weight at birth with an obvious centre was 1 750 g (in the above mentioned boy) Table 3 presents a correlation between the length at birth and visible nuclei, these occurred in 2 girls 44 cm in length The frequency of the centres in the 14 newborns in mothers with a diagnosis of toxicosis gravidarum was not different from that of the whole material

Comments

The data obtained in this investigation on the presence of an ossification centre in the head of the humerus in Swedish newborn children during the period 1965—1969 are in good accord with those published by CHRISTIE 1949) for white boys and girls at the Johns Hopkins Hospital during the period 1936—1938 The present material is genetically heterogeneous but unfortunately no detailed investigation of possible differences between different ethnic groups was feasible with the data available For the practical purpo es of clinical diagnosis of traumatic conditions of the shoulder joint it should be noted that a nucleus is evident in the head of the humerus in more than 50 per cent of all mature newborn children This figure is opposed to the statement in most textbooks of radiology and orthopedic surgery that the head of the humerus in newborns has no ossification centre

SUMMARY

The time of appearance of the ossification centre in the proximal epiphysis of the humerus was investigated roentgenologically in 144 newborn children within 24 hours of birth A nucleus was present in more than 50 per cent of all these at term and definite correlation existed b tween the weight at birth and time of appearance and size of the bone nucleus

Table 1

Correlation between gestational age (days) and the presence of an ossification centre in the proximal epiphysis of the humerus in 144 newborns examined within 24 hours of birth

Gestational age (days)	< 249			250—259			260—269			270—290			291—300			> 300		
Number examined	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total
	19	24	43	8	9	17	4	8	12	23	32	55	9	3	12	2	3	5
Number with nuclei	0	2	2	3	1	4	2	1	3	14	12	26	6	2	8	0	2	2
Percentage with nuclei	—	8	5	38	11	24	50	13	25	61	38	47	67	67	67	—	67	40

Table 2

Correlation between weight at birth and the presence of an ossification centre in the proximal epiphysis of the humerus in 144 newborns examined within 24 hours of birth

Weight at birth (g)	< 2 500			2 501—3 000			3 001—3 500			3 501—4 000			> 4 000		
Number examined	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total
	22	24	46	12	16	27	20	17	37	10	15	25	2	7	9
Number with nuclei	1	1	2	5	1	6	10	7	17	8	7	15	2	4	6
Percentage with nuclei	[illegible]	4	4	42	7	22	50	41	46	80	47	60	100	57	67

Table 3

Correlation between the length at birth and the presence of an ossification centre in the proximal epiphysis of the humerus in 144 newborns examined within 24 hours of birth

Length (cm)	< 44.0			44.1—45.9			46.0—47.9			48.0—49.9			50.0—51.9			52.0—53.9			54.0—55.9		
Number examined	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total
	14	11	25	2	6	8	9	10	19	13	13	26	16	18	34	8	14	22	3	7	10
Number with nuclei	2	0	2	0	1	1	0	0	0	5	1	6	8	5	13	8	7	15	3	6	9
Percentage with nuclei	14	0	8	0	17	13	0	0	0	38	8	23	50	28	38	100	50	68	100	86	90

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CONTRAST FILLING OF THE PULMONARY LYMPHATIC SYSTEM IN THE DOG

by

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Warren & Drinker (1942) demonstrated that the lymph drainage of both lungs of the dog is mainly into the right thoracic duct but that a small part goes to the left thoracic duct Correll & Langston (1958) concluded that the lymph flow of each pulmonary lobe is basically ipsilateral and that the flow from the lower lobes rarely drains into the lymph channels of other lobes Joitner & Ranniger (1968) also working with dogs tried to demonstrate communications between the cervical and thoracic lymphatics and injected the mediastinal nodes with contrast medium They reported that the paratracheal lymph ducts may drain into the venous system through the right thoracic duct The present experimental work was planned with the idea of demonstrating the lymphatic channels of the lungs by outlining the right thoracic duct at its point of entry into the venous system

Material and Methods General endotracheal anesthesia was used in 16 adult mongrel dogs The right thoracic duct was identified and cannulated at its junction with the jugulosubclavian angle with a 5 mm ID polythene tube Ultra fluid lipiodol was automatically injected in variable amounts in each dog at a

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ZUSAMMENFASSUNG

Der Zeitpunkt des Auftretens des Ossifikationszentrums der proximalen Epiphyse des Humerus wurde röntgenologisch bei 144 neugeborenen Kindern innerhalb von 24 Stunden nach der Geburt untersucht. Ein Nukleus war bei mehr als 50 % der ausgetragenen Kinder vorhanden, und es fand sich eine klare Korrelation zwischen dem Geburtsgewicht, dem Zeitpunkt des Auftretens und der Grösse des Knochenkerns.

RÉSUMÉ

Les auteurs ont étudié radiologiquement sur 144 enfants nouveau-nés au cours des 24 premières heures la date d'apparition du centre d'ossification de l'épiphyse proximale de l'humérus. Il y avait un noyau épiphysaire chez plus de 50 pour cent de ces nouveau-nés à terme et il y avait une nette corrélation entre le poids à la naissance et la date d'apparition ainsi que la taille du noyau osseux.

REFERENCES

Beckman, L.: A contribution to the physical anthropology and population genetics of Sweden. Hereditas 45 (1959) 1.

Christie, A.: Prevalence and distribution of ossification centers in the newborn infant. Amer. J. Dis. Child. 77 (1949) 355.

Elgenmark, O.: The normal development of the ossific centers during infancy and childhood. Acta paediat. scand. 33 (1946) Suppl. No. 1.

Garn, S. M., Rothmann, C. G. and Silverman, F. N.: Radiographic standards for postnatal ossification and tooth calcification. Med. Radiogr. Photogr. 43 (1967) 45.

Lemperg, R. and Liliequist, B.: Dislocation of the proximal epiphysis of the humerus in newborns. Acta paediat. scand. 59 (1970) 377.



Fig 7 Isolated lungs with bilateral di tribution of medium after pressure injection into right thoracic duct Lymphatic channels and pulmonary veins filled in both figures and the left atrium in (b) the t a hea lies in the lower half of the figures

The flow of medium is against stream and the filling of the lymphatic channels is achieved becau e the injection is performed under pressure which overcomes the natural resi tance of the normal flow (centripetal) as well as the valves of the ducts this probably explains why the lymphatics appear to have a larger diameter than normal That contrast medium can flow upstream was demonstrated by CELIS et coll (1969) who filled the lymphatics of the heart and mediastinal nodes by pressure injection through the coronary arteries The present investigation as well as that of CORRELL & LANGSTON (1958) disclosed no lymph nodes within the pulmonary parenchyma SEKI et coll (1969) have previously been able to fill the paratracheal nodes by injection into the peribronchial tissue or into nodes below the carina

It would appear that this experimental investigation produces evidence that contrast medium injected under pressure will travel from the right thoracic duct into the lymphatic channels of the mediastinum It will then flow into the lymphatics of the lung and the subpleural system and finally into the pulmonary veins and left atrium having formed a fine widely distributed network This procedure represents a basis for further work on the mechani m of the thoracic dis emination of neoplastic and infectious lung di ease



a b

Fig 6 The pulmonary veins (→) filled by medium flowing from the lymphatic system still clearly visible at the periphery of the lungs

nels (Fig 2), the lymphatics of both lungs filled simultaneously although they were sometimes more evident on one side (Fig 3) Paratracheal nodes occasionally became visible during the initial phase of the injection (Fig 4)

The medium flowed from the pulmonary hilum centrifugally through fine lymphatics which became more delicate and numerous as they approached the surface of the lung (Fig 5), as time elapsed and more medium was injected, it was seen to flow into the pulmonary veins (appearing as broader channels in Fig 6 a) and eventually into the left atrium (Fig 6 b) Roentgenographic examinations of the isolated lungs revealed the delicate lymphatic peripheric network with the lipiodol filling the pulmonary veins and flowing into the left atrium (Fig 7)

Discussion

It appears that no similar procedure to demonstrate the lymphatic channels of the lung of the dog by injection of contrast medium into the right thoracic duct has been reported

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THREE DIMENSIONAL ESTIMATION OF RENAL SHAPE AND VOLUME AT ANGIOGRAPHY

by

V HEGEDUS

An important gain in angiography of the kidney was the introduction of selective catheterization of the renal arteries Several accounts of the increased information obtainable by selective angiography as compared to non-selective techniques have appeared during the past 15 years The present communication describes an easily accomplished method of three dimensional angiography to improve the estimation of the renal shape and mass

Two kidneys of different sizes from a patient with renal hypertensive disease appear in Fig 1 This difference appears in the a p views to be slight and the surface of the right kidney is 95 5 per cent of that of the left kidney, with the difference in the lateral projection included in the calculation, the difference in volume becomes 67 5 per cent An infinite number of projections are needed to represent an irregular body three dimensionally Standard projections are often chosen ideally at an angle of 90 to each other The a p *and ipsilateral* posterior oblique projections are usually used in selective angiography of the kidney as in survey films and at urography These contribute to the stereoscopic impression but often fail to yield enough information regarding the appearances of the ventral and dorsal surfaces of the kidney the associated cortex the sinus and the pelvis A combination of essentially different projections preferably at right angles as in conventional roentgenography is more desirable The kidney being

Submitted for publication 23 November 1970

SUMMARY

A procedure for the demonstration of the pulmonary lymphatic system in the dog is described. This represents a basis for further work on the mechanism of thoracic dissemination of neoplastic and infectious pulmonary diseases.

ZUSAMMENFASSUNG

Es wird ein Verfahren zum Nachweis des pulmonellen lymphatischen Systems beim Hund beschrieben. Diese bildet eine Basis für weitere Arbeit über den Mechanismus der Verbreitung von Neoplasmen im Thorax und infektiöser Lungenerkrankungen.

RÉSUMÉ

Description d'une technique pour mettre en évidence le système lymphatique pulmonaire du chien. Elle représente un point de départ pour un travail ultérieur sur le mécanisme de la dissémination thoracique des affections pulmonaires néoplasiques et infectieuses.

REFERENCES

Celis A., Mena M. A. y Del Castillo H.: Flujo linfático y recuperación cardiaca en el paro y fibrilación ventricular determinados con los métodos más usuales en cirugía y transplante de corazón. (In Spanish.) Cirug. y Ciruj. 37 (1969) 10.

Cordell Jr. N. O. and Langston H. T.: Pulmonary lymphatic drainage in the dog. Surg. Gynec. Obstet. 107 (1958) 284.

Johner C. H. and Ranniger K.: Mediastinal lymphography. Surg. Gynec. Obstet. 127 (1968) 1313.

Seki Y., Haneda Y., Miyazaki T. and Suzuki C.: A new method for radiographic visualization of the bronchopulmonary lymphatic system. Radiology 92 (1969) 335.

Warren M. F. and Drinker C. K.: The flow of lymph from the lungs of the dog. Amer. J. Physiol. 136 (1942) 207.

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THREE DIMENSIONAL ESTIMATION OF RENAL SHAPE AND VOLUME AT ANGIOGRAPHY

by

V HEGEDÜS

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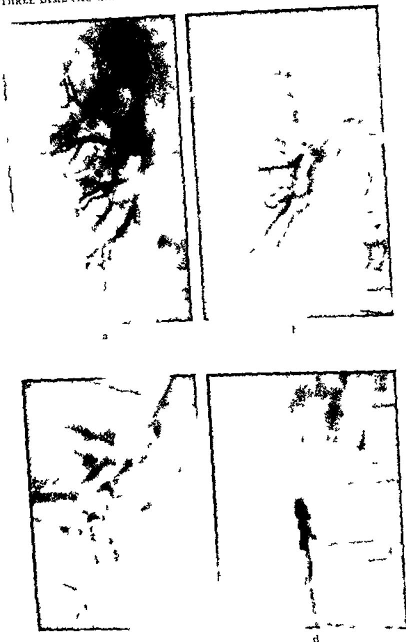


Fig R lation hip between projection and d stortion a) true a p b) a p c) lateral d) true lateral projection Distortion due to obliquity (b c) l teral di tal open angle (c d) ventral distal open angle (a b)



Fig. 1. Kidneys from a patient with marked hypertension. A.p. projection (above) and axial projection to demonstrate thickness of kidneys (below).

mobile and as several angles exist between the kidney and the main planes of the body, the problem is one of some difficulty. The kidney, in addition to its obliquity in relation to the sagittal plane of the body, subtends varying angles to the long axis of the body: these angles are open laterally distally and ventrally distally.

The relationship between the actual renal outlines and their distortions when viewed in projections ordinarily available for angiography appear in Fig. 2. It may be concluded that the true a.p. and true lateral projections of the kidney are the least distorted from the true outline, that the true a.p. projection is often, and the lateral projection invariably obscured by the lumbar spine, furthermore that the most suitable procedure to reduce distortion is to combine the two true projections. The true a.p. projection of the kidney, however, is disturbed to such a degree by masking of the spine and ribs that finer angiographic distinctions cannot be made. The most feasible compromise would therefore appear to be to combine the a.p. projection referable to the body of the patient and the true lateral (hereafter denoted "lateral") projection of the kidney.

Material. A total of 69 roentgenologically normal kidneys (42 right and 27 left kidneys) have been examined with selective angiography in the a.p. and lateral projections, 38 kidneys were in female and 31 in male patients while in

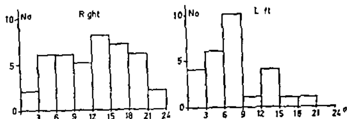


Fig 5 Variations in the ventral distal open angle Average angle on the right 12 and on the left side 8

vertebrae immediately adjacent to the upper and lower poles of the kidney (Fig 4) The angle varies widely in different patients as well as from side to side in the same patient and is probably dependent on the relation of the kidneys to the lumbar muscles and pelvis as well as on the position of the patient The angle further varies with the respiratory pha e The angle was usually larger on the right than on the left side (Fig 5) was greater on the right ide in 12 of the 16 patients with bilaterally normal kidneys only one of whom had the same angle bilaterally

The shape of the kidney in the lateral projection The kidneys were grouped into four types (Fig 6) (I) the ovoid type with a smooth surface (II) the ovoid type with a lobulated surface (III) kidneys with indentations from the liver or pleen and (IV) kidneys with large hilar lips

Six of the kidneys had two or three of these characteristics and were classified according to the most dominant The frequency of indentations of the left kidney by the spleen was twice as great as those of the liver on the right kidney (Fig 7) In half of the patients who had bilaterally normal kidneys both were similar in shape

The maximum renal thickness was measured in the lateral projection along a line perpendicular to the long axis of the kidney Fig 8 gives the variations in the thickness of the kidneys Of the 16 patients examined bilaterally 6 had a thicker right kidney 8 a thicker left kidney and 2 patients had the same thickness bilaterally The relationship between the length and thickness of the kidneys is summarized in Fig 9

Volume Measurement was made of the volume of 64 kidneys (41 right sided 23 left sided and 14 examinations bilateral) Problems arising from the magnifying and minifying factors as well as the appropriate geometric formula had to be solved to obtain the most accurate measurements possible

Magnifying factor Five patients of various weights and heights were examined A fine guide wire 50 mm from the tip of which a small silver bowl was welded

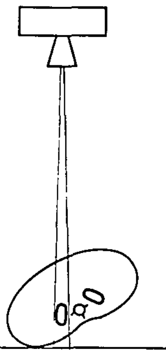


Fig 3 Method for obtaining a true lateral projection

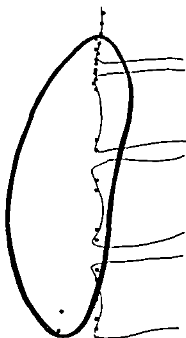


Fig 4 Measurement of the ventral distal open angle

16 patients the kidneys were normal bilaterally The ages were from 12 to 80 years in fairly equal distribution but with some overrepresentation in the 20 to 35 and 50 to 65 year age groups

Technique Percutaneous, transfemoral selective catheterization of the renal artery was performed in patients referred for various diseases A serial film examination was first made in the a p projection As the position of the renal pelvis in relation to the main planes of the kidney varies greatly, the lateral projection was positioned as follows The patient was placed on the side selected for examination and with the aid of fluoroscopy and, following the injection of about 5 ml of contrast medium into the renal artery, was rotated dorsally to a position lateral to the kidney (Fig 3) and a further series obtained Six to 10 ml of contrast medium were injected throughout with a thin walled catheter and a high pressure syringe at a speed of 10 ml per second Four roentgenograms obtained in both the a p and the lateral projections demonstrated the early arterial, arteriolo capillary, nephrographic and venous phases

The ventral distal open angle between the kidney and the long axis of the body may be determined in lateral films This angle is formed by the intersection of the long axis of the kidney and a line drawn from the anterior edge of the

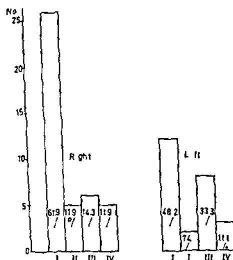


Fig 7 Classification of kidneys according to shape in the lateral projection

The variations in magnification were small the average linear magnification in the a p projection being 24 per cent while in the lateral projection it was 25 per cent Slightly less magnification (approximately 0 5 per cent) in the lateral projection must however always occur as the kidney is somewhat closer to the film than the site of origin of the renal artery

Minifying factors The obliquity of the kidney in relation to the sagittal plane of the body makes its width appear less in the a p projection than it really is The lateral distal open angle makes the length of the kidney appear shorter in the lateral projection both distortions having the effect of decreasing the ap-

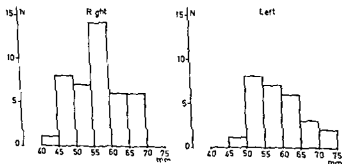


Fig 8 Classification of the kidneys according to thickness Average thickness on the right 57 3 mm and on the left side 59 9 mm

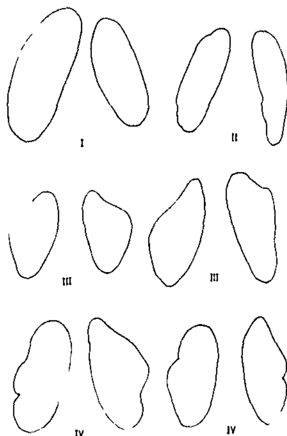


Fig. 6. The four types of kidney shape in the lateral projection

was introduced into the catheter placed into the renal artery. The tip of the guide wire was placed at the origin of the renal artery and a.p. and lateral views were obtained. The values of the linear magnification factors established were as follows:

A.p.	Lateral
24.81%	24.25%
	24.25%
24.81%	26.47%
	26.47%
23.08%	26.47%
	25.37%
23.67%	24.25%
	23.08%
23.67%	24.81%
	24.25%

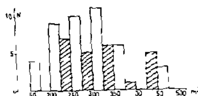


Fig. 10. Classification of the kidneys according to their roentgenologic volume. Average value on the right 29[illegible] cm³ (open fields) and on the left side 311 cm³ (hatched fields).

A summary of the sources of error of measurement of the volumes indicates that the average linear magnification of approximately 24.5 per cent is that of the volume of 57 per cent in the roentgenograms compared with the true volume. The resultant volumes must be diminished by the error of measurement inherent in the geometric formula of 6.4 per cent. A further difference between the calculated and the true volumes is ascribed to the obliquity of the kidney in relation to the sagittal plane of the body and its ventral distal angle and cannot be defined. The errors mentioned have not been incorporated in the estimated volume of the kidney, which is thus a measured size; it will be denoted as the roentgenologic volume of the kidney which is considerably larger than the true volume of the kidney. The variations in the roentgenologic volume are presented in Fig. 10.

The roentgenologic volume of the kidney has been related to the cross section surface of the artery. The measurements were performed in the a.p. projection and the diameter of the artery was determined close to the division into the primary branches. A comparison between the cross section surface of the artery and the roentgenologic volume of the kidney appears in Fig. 11. The value of the correlation coefficient is 0.48 which means a significant relationship between the above mentioned parameters although it fails to convey any information regarding the individual kidney.

Discussion

The location of the kidneys is described in the anatomic literature. CORNING (1931) and RAUBER & KOPSCH (1955) described the position of the kidney in relation to the longitudinal axis of the body. The literature has failed to reveal any technique for measuring the ventral distal angle possible only in the lateral projection. The same is true regarding the thickness of the kidney which is as important a factor as the other parameters of the renal shape. Classification of forms of the kidneys in the lateral projection will afford increased information beyond that provided in earlier descriptions.

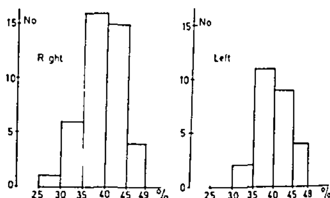


Fig. 9. Relationship between length and thickness of kidneys, the latter expressed as percentage of the length. Average value on the right 39.[illegible] and on the left side 40.6 per cent

parent size. The large variations in these angles made it impossible to devise a system for their elimination.

The geometric formula. The volume of a regular ellipsoid body may be represented by the formula

$$\frac{4}{3}\pi \cdot \frac{A \cdot B \cdot C}{2^3} = \frac{A \cdot B \cdot C \cdot \pi}{6}$$

where A, B and C indicate the length, width and depth of the body respectively. This formula adapted to the renal outlines measured at angiography means that A and B represent the length and width of the kidney as measured in the a.p. and C the thickest part of the kidney in the lateral projection. All these parameters were measured at right angles to each other in the nephrographic phase. The kidney shape approximates to that of an ellipsoid body although considerable variations in form are encountered. The formula was adapted to the shape of the kidney by measuring solid experimentally controllable bodies. Measurement of the axes A, B and C of kidneys at autopsy is inaccurate because of the softness of the kidneys. These become hard and deformed and are decreased in size by about 25 to 35 per cent after fixation. Fifty brown beans in the shape of kidneys were therefore substituted for the kidneys of cadavers; these were of different brands and sizes. The lengths of the axes corresponding to A, B and C were measured and the volumes calculated according to the formula. The estimated volumes varied between 188 mm³ and 661 mm³, the average being 378 mm³. The beans were then divided into groups of ten and their volumes determined according to the principle of Archimedes. The true volumes thus determined were greater than the volumes estimated according to the formula. The deviations were 6.10, 6.30, 6.35, 6.42 and 6.60 per cent. The average decreasing error of measurement was thus approximately 6.40 per cent.

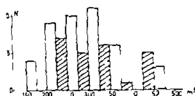


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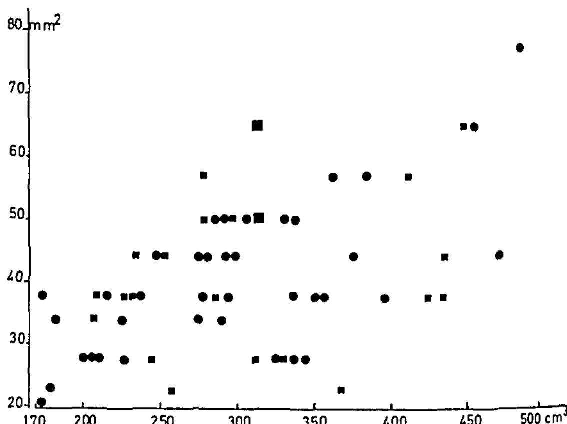


Fig. 11. Roentgenologic renal volume in relation to the arterial cross sectional area. ■ right, ● left, ■ both kidneys

The roentgen size of the kidney and its comparison to different pathologic changes has been discussed by many authors, e.g. IHLGREN & HÅKANSSON (1929), VUORINEN et coll. (1962) and HODSON et coll. (1961, 1966). MOELL (1961) measured the kidney in a.p. films and compared the area with the weight of the kidneys. FRIEDENBERG et coll. (1965) made a computer analysis of 1 285 kidneys examined in a.p. projection. Similar investigations were made by SCHULTZE & ZIMMERMANN (1965) inter alios. These communications have had in common the theory that a concept of the renal mass could be obtained by measuring the renal surface in only one projection. This is, as stated above, an unreliable method. The present investigation introduces the third dimension in measuring kidney volume which should aim at increasing accuracy in determining the size of the kidney.

Despite these distortions, the outline of the kidneys is probably reflected by the form of the brown beans and hence permits application of the ellipsoid formula for determination of apparent kidney volume. The greatest error in cal-

Table

Comparison between average kidney weight reported by HAUCH DE LEON WALD *and the present author with average values of roentgenologic renal volume measured*

Kidney weight (g)	HAUCH	DE LEON	WALD	Present material	Average weight	Roentgenologic volume (cm)	Average magnification error (o)
Right	128	115	—	122	121 7	293	59
Left	138	121	—	136	131 7	311	58
Male	14t	12?	159	—	14? 5	330	57
Female	119	114	127	—	120 0	?78	57

culating the volume of the kidney is caused by the varying obliquity of the kid ney and its lateral distal open angle The calculated renal volume is a roent genologic volume which permits compari on with other anatomic details at the same examination The roentgenologic kidney volume may be u ed in addition for approximate compari ons of the sizes of different kidneys estimated by the same method The accuracy is however not less than that of the estimation of the roentgenologic volume of other organs and considerably greater than that of the estimation of size by planimetric methods (WALK 1961 TOURU KAISILA 1970)

MOELI (1961) weighed 74 kidneys and compared them with their volumes determined by the Archimedes principle He stated that the weight of the kid neys may be taken as an indication of their volume If it be permissible to com pare the roentgenologic volume with the weight of cadaver kidneys in a statis tical material there would appear to be good correlation between the roent genologic volume of the kidneys as estimated in the present material and the weight of kidneys as determined at autopsy by HAUCH (1901) DE LEON et coll (1933) WALD (1937) These authors reported that the male kidneys were usually larger than the female and that the left kidneys were larger than the right The present control measurements of 10 right and 10 left cadaver kidneys confirmed these reports

A significant difference between the true kidney size and the roentgenologic volume appears to exist i e the calculated volume is slightly more than twice the true volume in all groups (see the Table) As the kidney weights obtained at autopsy are not corrected for post mortem changes the compari ons in the Table are not as satisfactory as those obtained by u e of an appropriate correction HEGEDUS & FAARUP 1972)

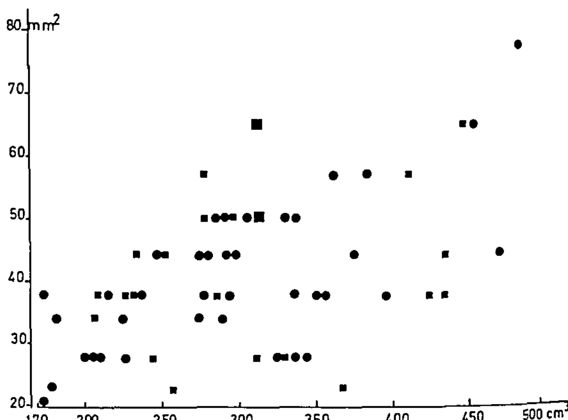


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HAUCH E Om nyrernes anatomi og deres udvikling (In Danish) Dissertation Copenhagen 1901

HEGEDÜS V and FAARUP P Cortical volume of the normal human kidney To be published in Acta radiol Diagnosis 12 (1972)

HODSON C J Physiological changes in size of the human kidney Clin Radiol 12 (1961) 91

— and CRAVEN J D The radiology of obstructive atrophy of the kidney Clin Radiol 17 (1966) 305

IDBOHRN H Renal angiography in experimental hydronephrosis Acta radiol (1956) Suppl No 136

KITTREDGE R D HEMLEY S D KANICK V and FINBY N The atrophic renal artery Amer J Roentgenol 92 (1964) 309

DE LEON W GARCIA A and DE JESUS P J Normal weights of visceral organs in adult Filipinos Philipp J Sci 52 (1933) 406

LUDIN H Zur quantitativen Bestimmung des relativen Nieren arterienkalibers Fortschr Rontgenstr 103 (1965) 604

— ELKE M FEHR H and THOELEN H Correlation of renal size renal artery calibre and effective renal plasma flow in man Acta radiol Diagnosis 6 (1967) 296

MOËLL H Kidney size and its deviation from normal in acute renal failure Acta radiol (1961) Suppl No 206

OLIN T Studies in angiographic technique Håkan Ohlssons Lund 1963

OLSSON O Renal angiography *In* Angiography Vol 2 p 539 Edited by H L Abrams Little Brown & Co Boston 1961

— (in collaboration with JONSSON G) Roentgen examination of the kidney and ureter *In* Encyclopedia of urology Springer Verlag Heidelberg 1962

RAUBER A und KOPSCH F Lehrbuch und Atlas der Anatomie des Menschen Georg Thieme Verlag Stuttgart 1955

SCHREIBER M H Renal artery — parenchyma ratios in the diagnosis of renovascular hypertension Amer J Roentgenol 96 (1966) 877

SCHULTZE H L und ZIMMERMANN S Zur Nierengrösse im Rontgenbild Z Urol Nephrol 58 (1965) 757

TILLGREN J och HÅKANSSON E Några interna synpunkter på rontgenundersokning av njurarnas storlek spec vid skrumpnjure (In Swedish) Hygiea 91 (1929) 345

TOURU KAISILA K Heart size determination by photofluorography Acta radiol (1970) Suppl No 295

WALD H The weight of normal adult human kidneys and its variability Arch Pathol 23 (1937) 493

WALK L Roentgenologic determination of the liver volume Acta radiol 55 (1961) 49

WOJTOWICZ J Relationship of the surface parameters of the kidney to the size of renal artery Invest Radiol 2 (1967) 231

VUORINEN P ANTTILA P WEGELIUS L et coll Renal cortical index and other roentgenographic renal measurements Acta radiol (1962) Suppl No 211

IDBOHRN (1956) in an investigation in rabbits demonstrated changes in the renal artery caliber as a result of a decreasing amount of the cortex but reported no statistical significance. KITTREDGE et coll. (1964), SCHREIBER (1966), LUDIN et coll. (1967) and WOJTOWICZ (1967) compared renal artery size with the functional capacity of the kidneys and their surface parameters, respectively. Low significant statistical relationship was evident in normal kidneys. A correlation between renal artery caliber and roentgenologic volume in the present material bears the same low significance as in the above publications.

Acknowledgement

The author takes this opportunity of thanking P. Faarup, Copenhagen, for the photography in Fig. 1.

SUMMARY

A method in combination with selective angiography for improving the estimation of the volume and shape of the kidney is described with reference to a material of 69 normal kidneys. The principles are discussed and the value of the roentgenologic renal volume is considered.

ZUSAMMENFASSUNG

Es wird eine Methode, um in Kombination mit der selektiven Angiographie die Abschatzung des Volumens und die Form der Niere zu verbessern, an einem Material von 69 normalen Nieren beschrieben. Die Prinzipien werden besprochen und der Wert des rontgenologisch bestimmten Nierenvolumens betrachtet.

RÉSUMÉ

L'auteur décrit sur une série de 69 reins normaux une méthode associée avec l'angiographie selective destinée à ameliorer l'estimation du volume et de la forme du rein. Il en discute les principes et examine l'interet de la mesure radiologique du volume renal.

REFERENCES

BLACK, D.: Renal disease. Oxford University Press 1964.

BOLIN, H.: Contrast medium in kidney during angiography. Acta radiol. (1966) Suppl. No. 257.

CORNING, H. K.: Lehrbuch der topographischen Anatomie. Bergmann Verlag, Munchen 1931.

FRIEDENBERG, M. J., BRUCE, J., WALZ, A. B. et coll.: Roentgen size of normal kidneys: a computer analysis of 1 286 cases. Radiology 84 (1965) 1022.

FRIMANN-DAHL, J.: Normal variations of the left kidney. Acta radiol. 55 (1961) 207.

HAUCH E Om nyrernes anatomi og deres udvikling (In Danish) Dissertation Copenhagen 1901
HEGEDUS V and FAARUP P Cortical volume of the normal human kidney To be published in Acta radiol Diagnosis 12 (1972)
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— (in collaboration with JONSSON G) Roentgen examination of the kidney and ureter *In* Encyclopedia of urology Springer Verlag Heidelberg 1962
RAUBER A und KOPSCH F Lehrbuch und Atlas der Anatomie des Menschen Georg Thieme Verlag Stuttgart 1955
SCHREIBER M H Renal artery — parenchyma ratios in the diagnosis of renovascular hypertension Amer J Roentgenol 96 (1966) 877
SCHULTZE H U und ZIMMERMANN S Zur Nierengrosse im Rontgenbild Z Urol Nephrol 58 (1965) 757
TILLGREN J och HÅKANSSON E Några interna synpunkter på rontgenundersokning av njurarnas storlek spec vid skrumpnjure (In Swedish) Hygiea 91 (1929) 345
TOURU KAISILA K Heart size determination by photofluorography Acta radiol (1970) Suppl No 295
WALD H The weight of normal adult human kidneys and its variability Arch Pathol 23 (1937 493
WALK L Roentgenologic determination of the liver volume Acta radiol 55 (1961) 49
WOJTOWICZ J Relationship of the surface parameters of the kidney to the size of renal artery Invest Radiol 2 (1967) 231
VUORINEN P ANTTILA P WEGELIUS U et coll Renal cortical index and other roentgenographic renal measurements Acta radiol (1962) Suppl No 211

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF O OLSSON),
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VASOPRESSIN IN THE ELIMINATION OF INTESTINAL GAS

by

JAN GOTHLIN

Patients with intestinal paresis were treated with a pituitary lobe extract by SCHAFER & HERRING (1906). BELL (1909) reported excellent results with the same drug under similar conditions. MELVILLE (1936) observed constriction of the small bowel and rapid propulsion of barium emulsion into the colon after the administration of pitressin. Vasopressin is one of the hormones secreted from the posterior lobe of the hypophysis. Apart from its antidiuretic effect, it causes smooth musculature to contract. Pitressin in doses of 5 to 20 units once to three times before abdominal roentgenologic examination was reported upon favourably by COLLINS & ROOT, JUTRAS & CANTERO and by SCHEIBEL at about this time. Several investigations have since been published in which vasopressin, more or less contaminated with oxytocin, has been used. As a synthetic vasopressin is now commercially available and as the criteria for the classifications of the results have not been performed in earlier reports the present work was undertaken.

Methods and Materials. Patients undergoing routine examination of the urinary tract, cholecystography, pelvis and lumbar spine prepared in various ways but still with disturbing gas in the preliminary roentgenograms have been

Submitted for publication 4 November 1970

Table 1

The patients grouped according to the type of discomfort Certain frequent combinations are grouped separately

	No of patients
Abdominal pain (incl tenesmus and flatulence)	72
Nausea (often combined with sweating)	59
Nausea + abdominal pain	22
Vertigo	14
Vertigo + abdominal pain	6
Vertigo + nausea	6
Dizziness	14
Emesis	12
Cold perspiration	8
Feeling of warmth	4
Fantasies	3
Syncope	2
Lassitude + shortage of breath	1
Decreased facial sensibility	1
Pressure in the head	1
Asthmatic paroxysm	1
No discomfort	194
Total	420

given 10 or 20 IU 8 lysine vasopressin (Postacton Ferring AB Sweden), subcutaneously A pilot investigation was first undertaken with 5 IU but as the results were unsatisfactory, the higher doses were chosen Patients with recent myocardial infarction were excluded No patients were pregnant Slight angina pectoris was not considered a contra indication

The results of the gas elimination have been classified in four groups excellent very good good and poor Excellent means complete elimination of gas from the intestines but not from the stomach The very good group consists of patients with a small amount of gas in the distal part of the rectum with a little outside the areas examined Good signifies that the gas remaining does not interfere with the interpretation Poor indicates incomplete gas removal Some removal of faeces in addition to gas was evident in all groups Four of the urographies were emergency examinations performed for ureteric calculi The arterial blood pressure was registered before and at 5 minutes after vasopressin and again when the first film was obtained in 50 patients At the second control an increase of about 5 mm Hg and at the third control a decrease of about 5 mm Hg compared with the first control were recorded

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Nausea (often combined with sweating)	9
Nausea + abdominal pain	22
Vertigo	14
Vertigo + abdominal pain	6
Vertigo + nausea	6
Dizziness	14
Emesis	12
Cold perspiration	8
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Table 2

The results at different intervals between the injection of vasopressin (10 and 20 IU grouped together) and the roentgen examinations The results are expressed as percentages of the 500 patients

Time (min)	Excellent	Very good	Good	Poor
15—30	1 5	3 5	1 0	0 5
30—45	10 5	27 0	9 0	3 0
45—60	2 5	12 5	7 5	2 0
60	3 0	8 0	7 5	1 0

Of 324 patients given 10 IU vasopressin 21 % were classed as excellent 52 % as very good 23 % as good and 4 % as 'poor The corresponding figures for the 176 patients receiving 20 IU of vasopressin were 25 % excellent 48 % very good 21 5 % good and 5 5 % poor The very good results predominate in both the series They were best in the younger subjects (Fig 3) although the degree of discomfort was greater (Fig 4)

Discussion

The effects of posterior pituitary lobe extracts on the gastrointestinal tract of animals have been investigated by several workers BELL (1909) FODERA & PITTAU (1909) MELVILLE & STEHLE (1934) WILLIAMS & STREETEN (1952), inter alios reported increased motility of the small intestines and the colon after the administration of the drug Posterior pituitary lobe extracts have been used in man for the treatment of intestinal paralysis by SCHAFER & HERRING (1906), BELL (1909) ELMER et coll (1930) RUNDLE (1935) SEED et coll (1937) and others Constriction of the small bowel and hastened passage into the colon of test meals have been demonstrated by e g MELVILLE (1936) this author investigated the effect of pituitary extract during barium meals GUTHRIE & BARGEN (1936) reported pitressin to be active within 3 to 5 minutes the effect lasting 45 to 60 minutes Posterior pituitary lobe extract as a remover of gas during a roentgen examination of the abdomen in man was investigated by COLLINS & ROOT JUTRAS & CANTERO and SCHLESSEL They administered 5 to 20 units of pitressin once to three times before the examination and obtained good results KENNING & LOFSTROM (1937) PAUL & BEATTY (1937) SMYRNIOTIS 1938) KIRKLIN & SEEDORF (1939) LEDOUX LEBARD & GARCIA CALDERON (1943) THOYER ROZAT et coll (1951) GHISLANZONI & GUERRINI (1951) and KENDALL (1960) also obtained good results in roentgen examinations of the

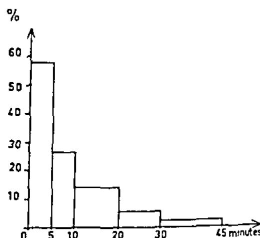


Fig 1 The interval between the injection of vasopressin (10 and 20 IU grouped together) and the onset of discomfort The percentage of the patients at different time intervals plotted on the y axis Total number of patients 260

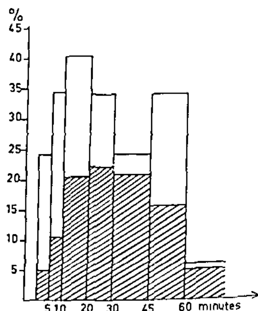


Fig 2 The duration of discomfort in 259 patients The patients are plotted in per centages on the y axis Unfilled staples represent 20 IU and filled staples 10 IU vasopressin

Results

No discomfort was reported in 46 % of 420 patients Facial pallor developed in all patients within 5 minutes Abdominal pain or nausea occurred in 65 % of the remaining 226 patients (Table 1) Discomfort usually started within 5 minutes in 83 % of 259 patients (Fig 1), it usually wore off in those receiving 10 IU vasopressin within 20 minutes but persisted longer in the 20 IU group (Fig 2)

Most patients fell into the 'excellent and very good groups when the interval between the administration of vasopressin and the roentgen examination was 30 to 45 minutes (Table 2)

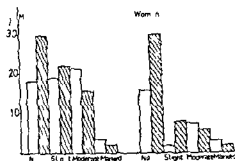


Fig 4 The degree of discomfort as a percentage in 420 patients (10 and 20 IU vasopressin grouped together) The filled staples represent patients over 50 years of age

results exists in age below 40 (Fig 2) This may be due to decreased sensitivity to vasopressin and a decreasing amount of smooth musculature with increasing age This differentiation in effect in varying ages does not seem to be mentioned in the literature

The intervals between the administration of drugs and the radiography vary in different investigations COLLINS & ROOT (1936 1937) give an interval of 45 to 60 minutes SCHEIBEL (1936) 150 and 30 minutes PAUL & BEATTY (1937) 30 minutes KENNING & LOFSTROM (1937) and KENDALL (1960) 30 to 45 minutes and SMYRNIOTIS (1938) 35 minutes The best results were obtained in the present investigation after an interval of 30 to 45 minutes (Fig 2)

KIRKLIN & SEEDORF (1939) reported that the side effects appeared at 10 to 20 minutes and lasted 30 to 60 minutes LINDQVIST (1967) stated that abdominal discomfort was most marked around 30 minutes and was disappearing within 60 minutes Discomfort commenced within 5 minutes in about 60 % and within 10 minutes in about 80 % of the patients affected (Fig 3) Facial pallor always arose within 5 minutes The interval between the injection of the drug and the onset of discomfort never exceeded 45 minutes Discomfort occurred in 226 out of 420 patients i e 46 % were free of symptoms The frequency of discomfort was not higher but more marked in the group receiving 20 IU of vasopressin than in the 10 IU group

A tendency for more side effects in the younger patients is evident The reason may be lower or decreased sensitivity of smooth muscle in old subjects (cf Fig 2) This is more marked in the 10 IU group and may be explained by the fact that it is larger and therefore more representative

All authors in describing the effects of vasopressin in doses over 1 IU mention pallor which is due to vasoconstriction of the skin Varying symptoms have been described the more common being abdominal tenesmus and diarrhoea nausea cold perspiration and dizziness Emesis weakness and asthmatic

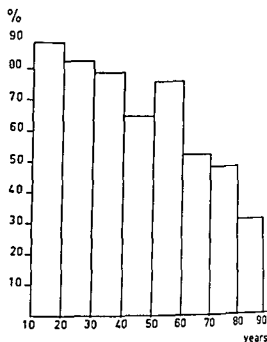


Fig. 3. Excellent and very good results grouped by ages. The figures on the y-axis indicate the percentages of the patients within each age group.

abdomen with various preparations of posterior lobe extracts. KLAMI & VUORINEN (1962) employed pitressin to eliminate gas in the digestive tract of patients in whom they were concerned with its origin. LINDQVIST (1967) used 8-lysine vasopressin before renal biopsies aided by fluoroscopy. The results were not based upon definite criteria and consequently are difficult to assess with any certainty.

The results in the present investigation were poor with 5 IU but satisfactory in patients receiving 10 and 20 IU of the drug, Postacton. The "excellent" and "very good" groups comprised three quarters of the total patients for both doses of vasopressin. COLLINS & ROOT (1936, 1937) obtained satisfactory results in 82 % of their patients and SCHEIBEL (1936) in 13 of 15 patients. PAUL & BEATTY (1937) reported satisfactory and fair results in 76 % of their patients. KIRKLIN & SEEDORF (1939) in 5 000 patients referred for cholecystography recorded that the number of re-examinations necessary was reduced from 25 % to 5 % or under. KENDALL (1960) registered 55 % "excellent and good" results compared with 37 % in controls. None of the above-mentioned authors indicated their criteria for their classifications.

It seems that the present results are at least as good as in the former investigations especially considering the fact that the percentage "poor" is as low as around 5, which figure represents the patients in whom the trial of new preparations was sometimes necessary. A dominance of "excellent" and "very good"

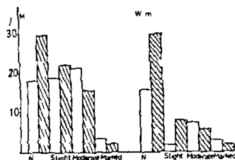


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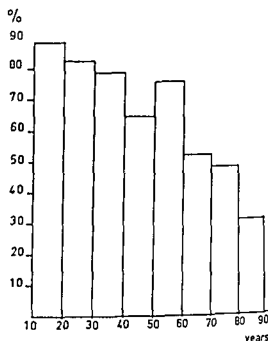


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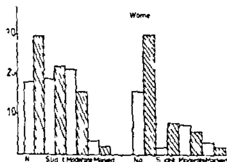


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paroxysm are less often encountered. Discomfort has been mentioned by, among others, COLLINS & ROOT (1936), SCHEIBEL (1936), KENNING & LOFSTROM (1937), PAUL & BEATTY (1937), SMYRNIOTIS (1938), KIRKLIN & SEEDORF (1939), GRAYBIEL & GLENDY (1941), BJERRE CHRISTENSEN (1952), SCHWARTZ et coll. (1959), SHALDON et coll. (1961), GROMOTKA & DEMLING (1962), LINDQVIST (1967), and ZAFFIRI & SESA (1967).

Pallor was observed in all patients of the present material. There was no correlation in its degree and other symptoms, of which abdominal discomfort predominated. Perspiration was common but has not been mentioned as a separate entity. Table 1 lists symptoms that the patients often had difficulty in explaining. Only one mild asthmatic paroxysm was included although several patients had this recorded in their case histories. LINDQVIST (1967) stated that one out of 3 patients in his material developed and asthmatic paroxysm after receiving vasopressin.

Much has been written on the cardiovascular effects of pituitary extracts of varying purity. Thus SCHAFER & HERRING (1908), HOLZ (1932), WAKIM et coll. (1954) and SHALDON et coll. (1961), inter alios, demonstrated various degrees of increased blood pressure in anaesthetized animals, the doses of the drugs varying widely. GEILING & CAMPBELL (1926), also in animals under anaesthesia, recorded an increase as well as a decrease in blood pressure while MELVILLE (1933) reported only a decrease. BOLIOBAS (1963) under the same conditions was satisfied that there was no change in the blood pressure in anaesthetized animals. TIGERSTEDT & AIRILA (1913) and KOLLS & GEILING (1925) noted bradycardia after the administration of the drug in non-anaesthetized animals and different doses of natural vasopressin, whereas FROMMEL & ZIMMET (1937) and BICKEL & FROMMEL (1937) observed a short period of tachycardia followed by a longer period of bradycardia. Evidence of coronary constriction has been demonstrated by DALE (1909), PAL (1909), and WEST & GUZMAN (1959) inter alios.

KOLLS & GEILING (1925) and SAWYER & ETTINGER (1943) recorded increased blood pressure after the administration of natural vasopressin in non-anaesthetized animals although MELVILLE (1936) observed a decrease. Bradycardia was demonstrated by KOLLS & GEILING (1925) and SAWYER & ETTINGER (1943). A short episode of tachycardia followed by a prolonged period of bradycardia was observed by GEILING & RESNIK (1925) and GRUBER & KOUNTZ (1930). Coronary spasm was described by RESNIK & GEILING (1925). Increased blood pressure was demonstrated by, among others, OLIVER & SCHAFER (1895), and KLEEMAN & CUTLER (1963) in non-anaesthetized males after the administration of various doses of posterior pituitary lobe extract of natural vasopressin. COLLINS & ROOT (1936, 1937) reported a decrease in blood

pressure one hour after the administration of the drug Bradycardia was mentioned by GROLLMAN & GEILING (1932)

Fewer investigations have been performed with synthetic vasopressin RIBOT et coll (1963) and LICHT (1965) recorded an increase in blood pressure in anaesthetized animals Increased blood pressure was demonstrated by TSAKIRIS & BUHLMANN (1961 1963; RIBOT et coll (1963), SHANKS (1963 1964), ARNER et coll (1965) and LICHT (1965) and bradycardia was demonstrated by TSAKIRIS & BUHLMANN (1961) in non anaesthetized human subjects Increased blood pressure and bradycardia were recorded by KATZ (1965) and LIGHT (1965) in such subjects under anaesthesia MOFFAT (1933) administered 20 units of pitressin to 62 patients and observed no sustained rise in blood pressure but rather a downward trend a fall in pressure occurred in 3 patients with hypertension COLLINS & ROOT (1936, 1937) noted an average increase of 10 mm Hg in a third of their patients after the administration of 10 units pitressin A drop in blood pressure was measured one hour after the *injection of the drug* in half of the patients

SEED et coll (1937) described a man with diverticulitis who developed a condition of short duration simulating shock that might have been due to the injection of 20 IU pitressin KIRKLIN & SEEDORF (1939) injected 20 IU of pitressin in 100 patients whose blood pressure fifteen minutes later fell The blood pressure was recorded every five minutes in an additional 5 *patients* an immediate slight rise was followed by a gradual drop

GRAYBIEL & GLENDY (1941) reported a 5 % decrease in cardiac output after the injection of 20 IU pitressin small changes in the pulse rate blood pressure and metabolic rate were evident and no pain developed in 2 *patients with* angina pectoris RUSKIN (1947) administered 10 units pitressin in *patients with* this condition Slight angina could sometimes be provoked, *no change or an in*crease in blood pressure of 10 to 20 mm Hg together with *bradycardia were recorded* MILLS et coll (1949) used 10 IU pitressin in 4 *patients with myo*cardial infarction in their extensive material ECG in 100 of their patients demonstrated almost no changes The *authors stated* that as pitressin was administered during routine cholecystography *cardiac disease may have been* mistaken for gallbladder dysfunction *WHITTLESEY (1950)* described 3 patients with coronary *infarction after* the administration of pitressin (dose not mentioned) *recorded by ECG* One of these *patients had known* coronary disease and the other 2 patients might have *been so affected* rather than by gallbladder changes SLOTNIK & TEIGLAND (1951) also reported 2 patients with cardiac infarction after the administration *of 20 IU* pitressin in routine cholecystography

BJERRE CHRISTENSEN (1952) administered 10 *units* pitressin to 120 patients

paroxysm are less often encountered. Discomfort has been mentioned by, among others, COLLINS & ROOT (1936), SCHIEBEL (1936), KENNING & LOFSTROM (1937), PAUL & BEATTY (1937), SMYRNIOTIS (1938), KIRKLIN & SFEDORF (1939), GRAYBIEL & GLENDY (1941), BJERRE CHRISTENSEN (1952), SCHWARTZ et coll. (1959), SHELDON et coll. (1961), GROMOTKA & DEMLING (1962), LINDQVIST (1967), and ZAHIRI & SFISA (1967).

Pallor was observed in all patients of the present material. There was no correlation in its degree and other symptoms, of which abdominal discomfort predominated. Perspiration was common but has not been mentioned as a separate entity. Table 1 lists symptoms that the patients often had difficulty in explaining. Only one mild asthmatic paroxysm was included although several patients had this recorded in their case histories. LINDQVIST (1967) stated that one out of 3 patients in his material developed and asthmatic paroxysm after receiving vasopressin.

Much has been written on the cardiovascular effects of pituitary extracts of varying purity. Thus SCHAFER & HERRING (1908), HOLZ (1932), WAKIM et coll. (1954) and SHELDON et coll. (1961), inter alios, demonstrated various degrees of increased blood pressure in anaesthetized animals, the doses of the drugs varying widely. GEILING & CAMPBELL (1926), also in animals under anaesthesia, recorded an increase as well as a decrease in blood pressure while MELVILLE (1933) reported only a decrease. BOLLOBAS (1963) under the same conditions was satisfied that there was no change in the blood pressure in anaesthetized animals. TIGERSTEDT & AIRILA (1913) and KOLLS & GEILING (1925) noted bradycardia after the administration of the drug in non-anaesthetized animals and different doses of natural vasopressin, whereas FROMMEL & ZIMMET (1937) and BICKEL & FROMMEL (1937) observed a short period of tachycardia followed by a longer period of bradycardia. Evidence of *coronary constriction has been demonstrated by DALE (1909), PAL (1909),* and WEST & GUZMAN (1959) inter alios.

KOLLS & GEILING (1925) and SAWYER & ETTINGER (1943) recorded increased blood pressure after the administration of natural vasopressin in non-anaesthetized animals although MELVILLE (1936) observed a decrease. Bradycardia was demonstrated by KOLLS & GEILING (1925) and SAWYER & ETTINGER (1943). A short episode of tachycardia followed by a prolonged period of bradycardia was observed by GEILING & RESNIK (1925), and GRUBER & KOUNTZ (1930). Coronary spasm was described by RESNIK & GEILING (1925). Increased blood pressure was demonstrated by, among others, OLIVER & SCHAFER (1895) and KLEEMAN & CUTLER (1963) in non-anaesthetized males after the administration of various doses of posterior pituitary lobe extract of natural vasopressin. COLLINS & ROOT (1936, 1937) reported a decrease in blood

ZUSAMMENFASSUNG

Etwa 5 000 Patienten die fur rontgenologische Untersuchungen des Abdomens eingewiesen waren wurde Vasopressin subcutan gegeben um Darmgas zu entfernen Die Ergebnisse bei 500 Patienten die eingehender untersucht wurden werden besprochen

RÉSUMÉ

Environ 5 000 malades adresses pour examen radiologique de l abdomen ont reçu une injection sous cutanee de vasopressine pour eliminer les gaz intestinaux L auteur examine les resultats obtenus chez les 500 malades qui ont ete examinees soigneusement

REFERENCES

ARNER O HAGBERG S SELDINGER S and SUNDBLAD R Effect of phenylalanin lysine vasopressin on portal pressure in man as measured by percutaneous transhepatic puncture Acta chir scand 130 (1965) 213

BELL W The pituitary body and the therapeutic value of the infundibular extract in shock uterine atony and intestinal paresis Brit med J (1909) 1609

BICKEL G et FROMMEL E Etude sur l action cardiaque de l extrait hypophysaire posterieur I L électrocardiogramme de la pitressine Arch int Méd exp 12 (1937) 309

BJERRE CHRISTENSEN K The pitressin test of renal concentrating capacity Acta med scand 142 (1952) 215

BOLLOBÁS B Experimentelle Untersuchungen zur Wirkung von Octapressin auf operative Agressionen Wien med Wschr 113 (1963) 275

CARLSON H Effect of posterior pituitary lobe extracts on the intestine of man and animals Proc Soc exp Biol (N Y) 27 (1930) 777

COLLINS E and ROOT J Elimination of confusing gas shadow during cholecystography by the use of pitressin J Amer med Ass 107 (1936) 32

— — Cholecystography further observations on use of pitressin and evaluation of other procedures Radiology 29 (1937) 216

— — Newer developments in cholecystography Cleveland Clin Quart 4 (1937) 85

DALE H The action of extracts of the pituitary body Biochem J 4 (1909) 427

ELMER A PTASZEK L und SCHEPS M Die Wirkung des Vasopressins und Oxytocins auf die Darmperistaltik und die Behandlung der Darmlahmungen (Ileus paralyticus) mit Vasopressin Klin Wschr 9 (1940) 1765

FODÉRA F et PITTAL L Etudes sur l hypophysis cerebri Arch ital Biol 7 (1909) 370

FROMMEL E et ZIMMET D Étude sur l action cardiaque de l extrait hypophysaire posterieur II Ischémie coronarienne et aire cardiaque Arch int Méd exp 12 (1937) 323

GEILING E and CAMPBELL D Variations in blood pressure induced by repeated injections of the posterior lobe of the pituitary gland J Pharmacol exp Ther 29 (1926) 449

— — and PESNIK W The action of pituitary tartrate on the heart of the unanesthetized dog J clin Invest 1 (1925) 239

GHISLANZONI R e GUERRINI G Proposta di un metodo farmacologico per l eliminazione della a rocolica (In Italian) Radiol med 37 (1951) 113

GOTHLIN J 8-lysin vasopressin för att eliminera tarmgas vid abdominell rontgendiagnostik Lecture held at Medicinska Riksstamman Stockholm 1969 (In Swedish) Nord med 84 1970 1312

and observed no cardiac symptoms or signs even in 3 patients with a typical history of angina pectoris In another experiment only one of 10 patients with a history of angina pectoris given 40 units pitressin presented changes in the ECG compatible with coronary spasm RIBOT et coll (1963) by infusing lysine vasopressin in doses of 2 5 to 3 IU demonstrated a slight increase in the pulmonary and systemic blood pressure and a slight decrease in cardiac output SECFI et coll (1963) with the same drug in infusion doses of 3 to 5 IU per minute obtained similar results

ISAKIRIS & BUHLMANN (1963) by infusing 1 IU lysine vasopressin per minute secured an increase in systolic blood pressure of 20 to 25 mm Hg and a rise in diastolic pressure of 13 to 15 mm No changes in the ECG and no angina pectoris were registered LICHT et coll (1965) administered 5 IU lysine vasopressin i v and observed an increase in systolic blood pressure of 30 mm Hg lasting 30 to 40 minutes but no changes in the ECG LINDQVIST (1967) injected 5 to 15 IU lysine vasopressin s c in 102 patients and in a further 11 with a B P 160 mm systolic The average blood pressure failed to rise after the injection Two patients had previously had angina pectoris but experienced no symptoms after vasopressin LUNDERQUIST (1969) had had a case of myocardial infarction after the injection of 20 IU pitressin

SCHWARTZ et coll (1959) administered 20 units pitressin to a patient with an old posterior myocardial infarction, no untoward effects were observed The drug 8 lysine vasopressin has been tested by the present author in a few patients with postoperative intestinal paralysis and in a few with meteorism to see if it had any effect in those conditions The results together with the earlier favourable reports justify further investigations

Conclusions

The drug 8 lysine vasopressin has proved to be a good gas remover in roentgenologic abdominal examinations More than 5 000 patients have been examined and 500 have been closely investigated A dose of 10 IU is suitable, *producing only slight or moderate discomfort in 54 % of patients* There seems to be no danger in employing this form of preparation of the bowel even with cardiac symptoms or recent myocardial infarction

SUMMARY

About 5 000 patients referred for roentgenologic examination of the abdomen have been given vasopressin subcutaneously to eliminate intestinal gas The results in the 500 who were closely investigated are discussed

ZUSAMMENFASSUNG

Etwa 5 000 Patienten die fur rontgenologische Untersuchungen des Abdomens eingewiesen waren wurde Vasopressin subcutan gegeben um Darmgas zu entfernen Die Ergebnisse bei 500 Patienten die eingehender untersucht wurden werden besprochen

RÉSUMÉ

Environ 5 000 malades adresses pour examen radiologique de l abdomen ont reçu une injection sous cutanee de vasopressine pour eliminer les gaz intestinaux L auteur examine les resultats obtenus chez les 500 malades qui ont ete examinees soigneusement

REFERENCES

ARNÉR O HAGBERG S SELDINGER S and SUNDBLAD R Effect of phenylalanin lysine vasopressin on portal pressure in man as measured by percutaneous transhepatic puncture Acta chir scand 130 (1965) 213

BELL W The pituitary body and the therapeutic value of the infundibular extract in shock uterine atony and intestinal paresis Brit med J (1909) 1609

BICKEL G et FROMMEL E Etude sur l action cardiaque de l extrait hypophysaire postérieur I L électrocardiogramme de la pitressine Arch int Méd exp 12 (1937) 309

BJERRE CHRISTENSEN K The pitressin test of renal concentrating capacity Acta med scand 14? (1952) 215

BOLLOBÁS B Experimentelle Untersuchungen zur Wirkung von Octapressin auf operative Agressionen Wien med Wschr 113 (1963) 275

CARLSON H Effect of posterior pituitary lobe extracts on the intestine of man and animals Proc Soc exp Biol (N Y) 27 (1930) 777

COLLINS E and ROOT J Elimination of confusing gas shadow during cholecystography by the use of pitressin J Amer med Ass 107 (1936) 32

— — Cholecystography further observations on use of pitressin and evaluation of other procedures Radiology 29 (1937) 216

— — Newer developments in cholecystography Cleveland Clin Quart 4 (1937) 85

DALE H The action of extracts of the pituitary body Biochem J 4 (1909) 427

FLMER A PTASZEK L und SCHEPS M Die Wirkung des Vasopressins und Oxytocins auf die Darmperistaltik und die Behandlung der Darmlahmungen (Ileus paralyticus) mit Vasopressin Klin Wschr 9 (1940) 1765

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FROMMEL F et ZIMMET D Étude sur l action cardiaque de l extrait hypophysaire postérieur II Ischémie coronarienne et aire cardiaque Arch int Méd exp 12 (1937) 323

GEILING E and CAMPBELL D Variations in blood pressure induced by repeated injections of the posterior lobe of the pituitary gland J Pharmacol exp Ther 23 (1926) 449

— — and RESNIK W The action of pituitary tartrate on the heart of the unanesthetized dog J clin Invest 1 (1925) 239

GHISLANZONI R e GUERRINI G Proposta di un metodo farmacologico per l eliminazione della aerocolica (In Ital an) Rad ol med 37 (1951) 113

GOTHLIN J 8-lysin vasopressin för att eliminera tarmgas vid abdominell rontgendiagnostik Lecture held at Medicinska Riksstamman Stockholm 1969 (In Swedish) Nord med 84 (1970) 1312

GRAYBIEL A and GLENDY R Circulatory effects following the intravenous administration of pitressin in normal persons and in patients with *hypertension and angina pectoris* Amer Heart J 21 (1941), 481

GROLLMAN A and GEILING E Cardiovascular and metabolic reactions of man to intramuscular injection of posterior pituitary liquid (pituitrin) pitressin and pitocin J Pharmacol exp Ther 46 (1932), 447

GROMOTKA R und DEMLING L Der Einfluss von Vasopressin auf die Darmdurchblutung des Menschen Klin Wschr 30 (1962) 456

GRUBER L and KOUNTZ W *The electrocardiogram of non anesthetized dogs as modified by* the intravenous injection of pitressin atropine sulphate and vagus section J Pharmacol exp Ther 40 (1930) 253

GUERRINI G e GHISLANZONI R L associazione postipofisiprotigmina sull apparato digerente (In Italian) Arch Radiol diagn (Bologna) 23 (1951) 6

GUTHRIE J and BARGEN J The effects of drugs on different segments of the intestine of man Surg Gynec Obstet 63 (1936) 743

HOLZ P *The action of pituitary posterior lobe extracts of different parts of the circulatory* system J Physiol 76 (1932) 149

JUTRAS A et CANTERO A Le pitressin hormone antipneumatosique son emploi dans le radiodiagnostic abdominal J Radiol 20 (1936) 443

KATZ R Epinephrine and PLV 2 cardiac rhythm and local vasoconstrictor effects Anesthesiology 26 (1965) 619

KENDALL R Experience with antidiuretic hormone in excretory urography J Urol 84 (1960), 577

KENNING J and LOFSTROM J The elimination of intestinal gas shadows in roentgenography Preliminary report of 1 000 cases Amer J Roentgenol 37 (1937) 28

KIRKLIN B The use of pitressin in cholecystography Proc Mayo Clin 32 (1939) 502

— — and SEEDORF E A clinical study of the reactions following employment of pitressin in cholecystography Amer J Roentgenol 42 (1939) 811

KLAMI P and VUORINEN P Roentgenologic observations on gastrointestinal gas and its passage Ann Med intern Fenn 51 (1962) 49

KLEEMAN C and CUTLER R The neurohypophysis Ann Rev Physiol 25 (1963) 385

KOLLS A and GEILING E Contribution to the pharmacology of extracts of the posterior lobe of the pituitary gland J Pharmacol exp Ther 24 (1925) 67

LEDOUX LEBARD R et GARCIA CALDERÓN J Technique du radiodiagnostic p *737 752* Masson et Cie Paris 1943

LIGHT G RATTENBORG C and HOLADAY D A new vasoconstrictor preliminary studies of Phelypressin Anesth Analg Curr Res 44 (1965) 280

LINDQVIST B Vasopressin as an aid in locating the kidney in roentgen television for renal biopsy Acta med scand 181 (1967) 97

LUNDERQUIST A Personal communication (1969)

MELVILLE K *The action of pituitary extract upon the blood pressure of the normal unan*esthetized animal and the effects of ephedrine or adrenaline thereupon J Pharmacol exp Ther 47 (1933) 355

— Pressor and oxytoxic fractions of posterior pituitary extract comparative effects on blood pressure and intestinal activity J Amer med Ass 106 (1936) 102

— and STEHLE R The action of pituitary preparations (posterior lobes) upon the intestines of the dog J Pharmacol exp Ther 50 (1934) 165

MILLS M BURCHELL H PARKER R and KIRKLIN B Myocardial infarction and sudden deaths following the administration of pitressin additional electrocardiographic study of 100 patients given pitressin for cholecystography Proc Mayo Clin 24 (1949) 254

MOFFAT W The effect of pituitrin injection on blood pressure in man Amer J med Sci 186 (1933) 854

NECHELES H MASKIN M STRAUSS S et coll Effect of posterior pituitary extract on motility of the gastro-intestinal tract Arch Surg (Chic) 33 (1935) 780

OLIVER G and SCHAFER E On the physiological action of extracts of pituitary body and certain other glandular organs J Physiol 18 (1895) 277

— — Cited by JUTRAS A et CANTERO A

PAL J Über die Gefasswirkung des Hypophysenextraktes Wien Med Wchschr 59 (1909) 137

PAUL L and BEATTY S The use of pitressin for the elimina ion of intestinal gas in roentgenography of the genito-urinary tract and gallbladder Amer J Roentgenol 38 (1937) 776

RESNIK W and GEILING E The action of pituitary extract on the heart of the unanesthetized dog J clin Invest 1 (1925) 217

RIBOT S ABRAMOWITZ S KALHOFFER W et coll Cardiovascular effects of phenylalanyl 2 lysyl 8-vasopressin (PLV 2) Amer J med Sci 246 (1963) 137

RIBOT S GREEN H SMALL J and ABRAMOWITZ S Cardiovascular effects of vasopressin Amer J med Sci 242 (1961) 612

RUNDLE F Intravenous pituitrin in post-operative ileus Brit med J 2 (1935) 1208

RUSKIN A Pitressin test of coronary insufficiency Amer Heart J 34 (1947) 569

SAWYER M and ETTINGER G The cardiac action of posterior pituitary extract in physiological doses in the normal dog and after partial and complete denervation of the heart Canad J Res D 21 (1943) 311

SCHEIBEL O Concerning pitressin in roentgen examination of the abdomen as an agent for reducing shadow caused by intestinal gas Acta radiol 17 (1936) 511

SCHAFER E and HERRING P The action of pituitary extracts upon the kidney Phil Trans 199 B (1908) 1

SCHWARTZ S BALES H EMERSON G and MAHONEY E The use of intravenous pituitrin in treatment of bleeding esophageal varices Surgery 45 (1959) 72

SEED L FALLS F and FANTUS B Pitressin (betahypophamine) in laparotomies Surg Gynec Obstet 64 (1937) 895

SHALDON S DOLLE W GUEVARA L et coll Effect of pitressin on the splanchnic circulation in man Circulation 24 (1961) 797

SHANKS C Intravenous octapressin during halothane anaesthesia a pilot study Brit J Anesth 35 (1963) 640

— The compatibility of octapressin with cyclopropane trichlorethylene and halothane N Z med J 63 (1964) 156

SLOTNIK I and TEIGLAND J Cardiac accidents following vasopressin injection (pitressin) J Amer med Ass 146 (1951) 1126

SMYRNIOTIS P Quelques cas de radiographies apres injection de pitressin Épreuve expérimentale J Radiol 22 (1938) 68

THOYER ROZOT P PERROY A et FLOURIOT P L élimination des gaz coliques par le pitressin au cours du rad odiagnostic abdominal J Radiol 28 (1947) 407

TIGERSTEDT C und AIRILA Y Über die Einwirkung des Pituitrins auf die durch die Aorta strömende Blutmenge Skand Arch Physiol 30 (1913) 302

ISAKIRIS A und BÜHLMANN A Experimentelle Untersuchungen beim Menschen über die Wirkung von Vasopressin auf die Leberdurchblutung und den portalen Druck Helv med Acta 28 (1961) 615

— — Kreislaufwirkungen eines neuen synthetischen Vasopressins Dtsch med Wschr 1 (1963) 46

WAKIM K, DENTON C and ESSEX H Certain cardiovascular effects of vasopressin (pitressin) Amer Heart J 47 (1954) 77

WEST J and GUZMAN S Coronary dilatation and constriction visualized by selective arteriography Circulat Res 7 (1959), 527

WHITTLESEY F Pitressin and myocardial infarction W Va med J 46 (1950) 38

WILLIAMS I and STREETEN D The action of posterior pituitary extracts upon propulsion in the small intestine of conscious dogs Brit J Pharmacol 7 (1952) 47

ZAFFIRI O e SESIA C L octapressina in urologia (In Italian) Minerva urol 16 (1967) 164

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FOURTH VENTRICLE

I A morphologic and radiologic investigation of the normal anatomy

by

MARIO CORRALES and TORGNY GREITZ

Evaluation of the displacement and the deformity of the fourth ventricle is usually necessary to ascertain the site and extension of expanding lesions in the posterior fossa by encephalography and ventriculography It would appear from the literature that no systematic investigation of these changes has been made with due consideration to the anatomic details of the fourth ventricle The first step towards such an investigation therefore consisted in anatomic and roentgen determinations of the appearances of the fourth ventricle under normal conditions The clinical part of this investigation has to a certain extent been made possible through the progress of the technique of encephalography in later years due mainly to the easy application of tomography becoming available The present work is intended to serve as a complement to previous descriptions of the fourth ventricle and its appearances at pneumography

Earlier investigations The first detailed contribution to the anatomy was made by MAGENDIE (1825) who described the medial foramen that connects the fourth ventricle with the cisterna magna and bears his name The lateral recesses were discovered by BOCHDALEK (1849) and erroneously thought to be blind

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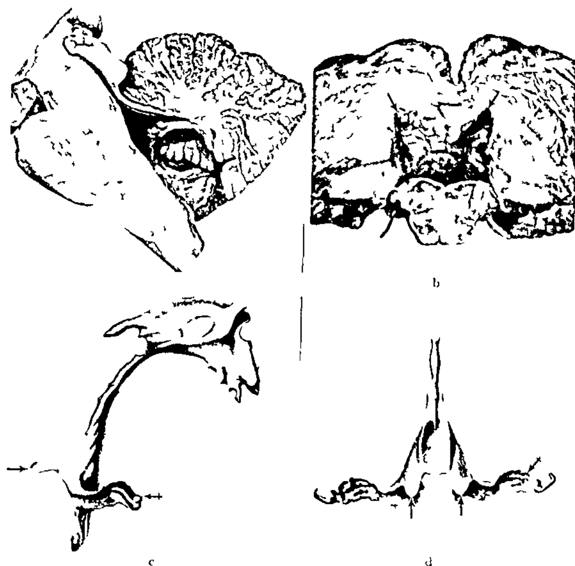


Fig. 1. Illustrations from RETZIUS' work on the fourth ventricle. Anatomic specimens of superior posterior recesses (authors' arrows). a) Parasagittal cut with the tonsil removed to expose the uvula and nodulus. The inferior limit of the superior posterior recess is formed by the posterior medullary velum continuous anteriorly with the tela choroidea. b) The posterior superior recesses are continuous anteriorly with the lateral recesses which embrace the brain stem at the level of the pons and medulla and open into the lateral part of the medullary cistern. c) d) Casts of the ventricular system. The fourth ventricle with its posterior superior recesses (—→) and its lateral recesses (+—→) from the lateral (c) and posterior (d) aspect.

extensions of the fourth ventricle. These recesses were later correctly revealed as channels communicating with the subarachnoid space by LUSCHKA (1855, 1859) and were submitted to a thorough examination by BLAKE (1900). RETZIUS (1896, 1900) described the posterior superior recesses in considerable detail (Fig. 1). Excellent casts that helped to elucidate the anatomy of the



Fig 2 Specimen with plastic cast in situ during dissection a) The fastigium (>—>) lies anterior to the superior recess (—>) Lateral recess (<—>) b) The tonsil is no longer in close contact with the superior posterior recess or lateral recess bordered inferiorly by the choroid plexus

fourth ventricle and its relation to surrounding structures were also made by TWINING (1939) and LAST & TOMPSET (1953)

The encephalographic appearances of the fastigium and the posterior superior recesses as evident in lateral views were first recorded by DAVIDOFF & DYKE in 1946 and later more fully by AMUNDSEN & GRIMSRUD (1966) and OBERSON et coll (1969) HUANG & WOLF (1967) in their paper dealing with the vein of the lateral recess demonstrated the true appearances of the posterior superior and lateral recesses as evident at encephalography

OBERSON (1969) recently described the encephalographic appearances of the anterior medullary velum and the posterior superior recesses The lateral recesses were displayed in the p a projection only The anatomic details as evident in the p a plane with different angulations of the roentgen beam were however not clarified, nor was any satisfactory account given of the fastigium as outlined in the a p projection OBERSON also claimed that the lateral recesses were rarely evident and stated that the superior posterior recess varied considerably in size and could be asymmetrically developed

Material and Methods Fifteen plastic casts of the fourth ventricle were made in order to analyze the topographic anatomy of the fourth ventricle with special regard to its appearances at encephalography and ventriculography The material used was partly a polyester resin with a mineral filler and dioxyl benzoyl peroxide as a catalyst (Plastic Padding) and partly a modified acrylate resin with a similar hardener (Castolite) The majority of these casts were removed by dissection to allow of an anlysis of the topography (Fig 2) Thirty



Fig. 3. Central ventriculography with water soluble contrast medium in the cadaver. The fastigium (>—→), the superior posterior recess (—→) and the lateral recess (+—→) as well as the indentation (↦→) at the level of the anterior part of the dentate nucleus just posterior to the origin of the lateral recesses are all outlined.

normal specimens of the cerebellum and brain stem were also dissected. Roentgen examination of the casts and air filled specimens were made in order to determine the influence of the projections on the appearances of the above mentioned anatomic details. Central ventriculography (AZAMBUJA et coll. 1956) in 18 cadavers with the body in the supine position was performed with 15 to 30 ml of water soluble contrast medium (Conray 60 % or Isopaque Cerebral). Lateral and several different half axial projections were then obtained in each case (Fig. 3).

The encephalographic appearances of the fourth ventricle were further analysed in a series of 100 cases without any signs or symptoms of posterior fossa changes. The technique was mainly that described by LINDGREN (1949) and ROBERTSON (1941) with certain modifications (GREITZ & GREPE 1967). To achieve the best filling of the fourth ventricle the head should be bent forward so as to bring the foramen of Monro to the same horizontal level as the canal of Magendie. The anterior part of the roof of the fourth ventricle, i.e. the velum, is best defined when the central beam is parallel to this structure. This is also true as regards the floor, which corresponds to an inclination of the central ray of about 30°. As the angle of the tomographic cut should not exceed 30° the roof and the floor cannot be depicted simultaneously. Tomography was applied as a routine in the material, the standard sweep was 16°. The magnification



Fig. 4. a) Section parallel to and just posterior to the floor of the fourth ventricle. The median sulcus and the two medial eminences with the rhomboid floor demarcated laterally and superiorly by the cerebellar peduncles and laterally and inferiorly by the insertion of the tela choroidea. The inferior angle is called the obex (⟼) the lateral angles are continuous with the lateral recesses (→→). b) Cut at the level of the floor. The lateral part of the left lateral recess has been exposed by removing the hemisphere. The choroid plexus (⟼⟼) forms the floor of the lateral recess and being attached medially to the tela choroidea (⊃→) constitutes the lateral inferior border of the fourth ventricle. The origin of the right lateral recess (→→) is separated from the posterolateral fissure (⟼) and the cerebello-medullary fissure (⟼) by the anterior extension of the posterior medullary velum. These fissures are bordered by the anterior extension of the tonsil. c) Section through the superior posterior recesses (—→) and the lateral recesses (→→). The upper pole of the tonsils protrude into the superior posterior recesses which are surrounded by two semilunar areas of grey matter the dentate nuclei. At the level of the anterior part of the dentate nucleus an indentation (⟼) is formed between the superior posterior recess and the lateral recess the opening of which lies laterally in the medullary center.

factor in tomography was 1 40 and constant it varied in the conventional film with the object film distance and was about 1 20

All locations and extensions of the anatomic structures will be oriented anteriorly i e perpendicular to the clivus and at right angles posteriorly



Fig 3 Central ventriculography with water soluble contrast medium in the cadaver The fastigium (>—→) the superior posterior recess (—→) and the lateral recess (→→) as well as the indentation (↔→) at the level of the anterior part of the dentate nucleus just posterior to the origin of the lateral recesses are all outlined

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a



b



c

F g 5) The r of of the fourth entricle from the floor wh ch has been removed by a section dent cal to th t in fig 4a Superio ly the med al part of the roof is formed by the velum (⤜→) and its l te al p rt by the b ach um conjunctivum (∞→) inf riorly it is made up of the nodulus in the midl e nd mor laterally by the upper pole of the tons l Th s part of the tonsil is covered poste r rly by th semilunar po ter or medullary velum (⊏→) the anterior margin of which is continuous w th th tela ch ro dea (⊃→) cove ing the remainder of the tonsil The anterior extension of the post r or medullary velum separates the cavity of the fourth ventricle from the posterolateral fis u (↔) b Midl e ut through th fast gium (↣) superior to th s the roof is fo med by the anterio m dull ry elum (⤜→) and by the l ngula and nferiorly by the nodulus (▶) c) A more lat r l cut th o gh the supe io post rior rec (⟶, here bo dered superiorly by the brachium c junct vum (↝) and the dentate nucleus (⊸→) and inferiorly by the posterior medullary lum (⊏→) co e g the upper pole of the tons l

superiorly and inferiorly. This means that the floor forms the most anterior extension of the body of the fourth ventricle and the fastigium and the superior posterior recesses its most posterior extension. These definitions imply that the posterior superior recesses should preferably be called the inferior posterior recesses. Nevertheless, the old nomenclature has been retained.

Anatomy of the fourth ventricle

The fourth ventricle is a cavity situated on the dorsal aspect of the pons and medulla oblongata in the anterior medial part of the cerebellum (Fig. 1). It is continuous superiorly with the aqueduct of Sylvius and inferiorly with foramen of Magendie. It has the appearance of a tent with a floor and four walls, its apex being the fastigium. The superior (anterior) and inferior (posterior) walls will be described as belonging to the roof, because they bear a less steep inclination to the floor than the lateral walls and because they do not reach the floor in the midline. The fourth ventricle has two symmetric anterior lateral extensions, the lateral recesses (Figs. 1, 4).

The *floor* corresponds to the dorsal aspect of the pons and medulla oblongata and has a characteristic rhomboid shape (Fig. 4 a) with its wider part at the level of the lateral recesses at the boundary between the pons and the medulla oblongata. The inferior margin of the floor corresponds to the obex (Figs. 4 a, 8, 9, 11). The insertion of the tenia choroidea runs from the obex in an oblique direction superiorly and laterally and is continuous laterally and anteriorly in the inferomedial part of the lateral recess. Superior to the lateral recesses the lateral margin of the floor is formed by the brachium conjunctivum, the brachium pontis and the restiform body, where the floor is continuous with the aqueduct. A longitudinal shallow sulcus (Fig. 4 a, b), the medial sulcus, is located in the midline of the floor between the two symmetric medial eminences.

The *lateral walls* are formed above the level of the lateral recesses by the superior, medial and inferior cerebellar peduncles (brachium conjunctivum, brachium pontis and restiform body, respectively) (Figs. 4 a, b, 5 b, c). The more posterior part of the wall is made up to the dentate nucleus which will be described with the roof. Inferior to the lateral recesses the lateral walls and the roof are formed by one and the same structure, the tela choroidea, covering the tonsils.

The *roof* may be divided into a superior and an inferior part, which in the midline join at the most posterior region of the ventricle, the fastigium (Figs. 2, 5 b, 6 b). The superior part begins at the level of the inferior boundaries of the inferior quadrigeminal tubercles and is formed medially by the anterior medul



a



b



c

Fig 5 The r of f the fourth ventricle f om the floor wh ch has been removed by a section id nt cal to that n fig 4a Superio ly the medial pa t of the roof is formed by the velum (»→) and it late al part by the brachium conjunctivum (∞→) nferiorly it s made up of the nodulus in the m dl n and m e later lly by the uppe pole of the tons l Th s part of the tons l is covered poste n rly by the m l nar posterior m dullary v lum (c→) the anterior marg n of which is continuous w th th t la h o dea (⊃→) cov r ng the remainder of the tonsil The anterior extens on of the pos ior med l ary velum separates th ca ity of the fourth entricle from the posterolateral fis re ↔ b Midl ne cut th ough the fastigium (↣) super or to this the roof is formed by the anter r m dull ry v lum (»→) and by the l ngula and infer o ly by th nodulus (▶) c) A more lat l t th ough the supe r r posteri r reces (→) here bo dered superiorly by the brachium conj nct um (∿→) and th d ntate nucleus (⊶) and inferiorly by the posterior medullary lum (c→ over ng th upp r pole of the tons l

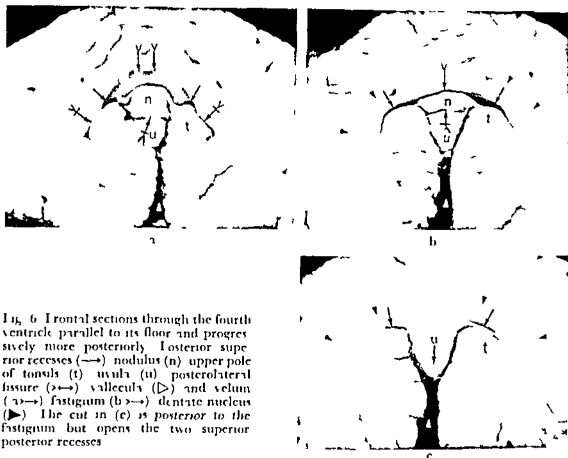


Fig. 6. Frontal sections through the fourth ventricle parallel to its floor and progressively more posteriorly. Posterior superior recesses (—→) nodulus (n) upper pole of tonsils (t) uvula (u) posterolateral fissure (>—→) vallecula (▷) and velum (a>—→) fastigium (b>—→) dentate nucleus (▶). The cut in (c) is *posterior to the fastigium* but opens the two superior posterior recesses.

lary velum covered by the lingula which is adjacent to the central lobulus of the vermis. The anterior medullary velum (Figs 5 a, b, 6 a) is inserted inferiorly at the posterosuperior aspect of the nodulus, the point of insertion is identical to the fastigium. More laterally, the superior part of the roof is formed by the brachium conjunctivum and its most posterior part by the dentate nucleus (Fig. 5 c). The fourth ventricle in its posterolateral aspect extends more posteriorly and inferiorly than the fastigium. These posterolateral extensions were called the posterior superior recesses by RETZIUS (1896) (Figs 1, 2, 4 c, 5 c, 6 b, c), they were always symmetrically developed in the 40 specimens examined by us. The roof of this recess is formed by the dentate nucleus and the floor by the upper pole of the tonsil, covered by the posterior medullary velum (Figs 2, 5 c). The posterior superior recess is bounded posteriorly and laterally by the dentate nucleus. In the most anterior part of the lateral aspect of the posterior superior recess, at the level of the anterior part of the dentate nucleus, an indentation (Figs 3, 4 c, 8) marks the boundary between the posterior superior recess and the lateral part of the origin of the lateral recess.

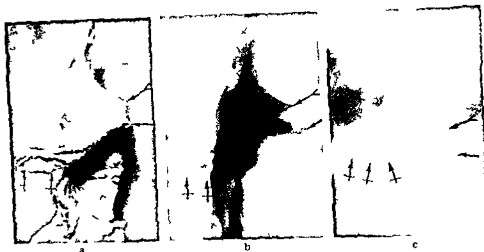


Fig 7 a) Cast of fourth ventricle b) Its roentgen appearances c) Midline tomogram (zonography) during encephalography in vivo Fastigium (→) posterior superior recess (—→) lateral recess (→→)

The inferior part of the roof (Fig 5 a) is formed medially by the nodulus partly covered by the choroidal plexus and laterally by the tonsils The upper pole of the tonsils i e the floor of the posterior superior recess is covered by the posterior medullary velum (Fig 5 a c) The latter is a semilunar structure continuous laterally and anteriorly with the floccular peduncle and inferiorly at its anterior and medial margin (Fig 5 a) with the tela choroidea which covers the remainder of the superior anterior surface of the tonsil The tela choroidea is attached to the borders of the inferior part of the floor (Fig 4 b)

The *lateral recesses* The fourth ventricle becomes continuous with two symmetric anterior extensions in its most lateral extensions corresponding to the widest portion of the floor These embrace the upper part of the medulla oblongata and are the lateral recesses which open laterally in the upper part of the medullary cistern (Figs 1 2 4 7 8 9 10 16 17) The lateral wall is formed by the floccular peduncle and the brachium pontis and the medial wall by the striae medullares and the restiform body The latter extends superiorly and also constitutes the superior limit of the lateral recesses The inferior boundary of the latter is produced by an extension of the posterior medullary velum (Fig 4 b) The choroid plexus in its medial part (Fig 4 c) is attached to the tenia choroidea i e the insertion of the tela choroidea which is close to the medial wall These structures separate the lateral recess from the space

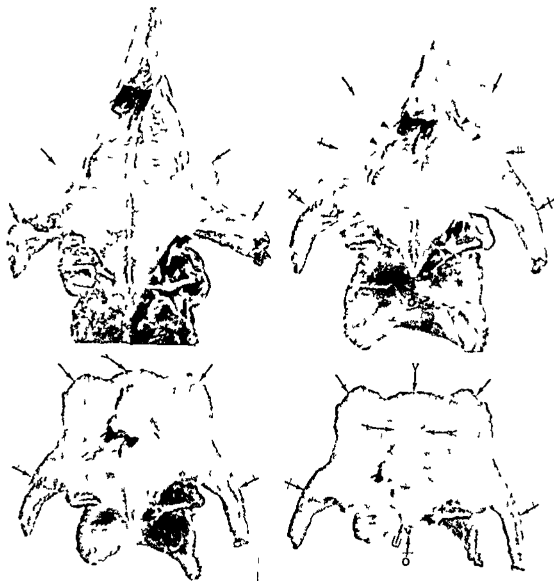


Fig 8 Influence of projection on the appearances of the fourth ventricle The fourth ventricle is projected successively more along its axis Cast of fourth ventricle The fastigium (>→) is located slightly higher follows the superior posterior recesses (—→) and may be projected above or below the velum (»→) It has an upward convex border as opposed to the anterior medullary velum which is straight or convex downwards Lateral recesses (+→) median sulcus (C→) lateral walls of the body (▶) indentation at dentate nucleus (↦) obex (ω→)

superior to the anterior extension of the tonsil, the posterolateral fissure of the cerebellum and, from the space between the tonsil and the medulla oblongata, the cerebello medullary fissure (Fig 4 b) The most anterior extension of the tonsil is at the level of the opening of the lateral recess into the medullary cistern (Fig 16)



Fig 9 Roentgen films of cast in fig 8

Encephalographic appearances of the fourth ventricle

The floor velum fastigium posterior superior recesses nodulus and upper pole of the tonsil were recognized in the lateral view in all 100 cases with normal findings at encephalography The posterior superior recesses were evident in all but 9 cases in the p a projection in 2 of these 9 cases the ventricular system was small and the recesses were probably very thin and in 5 cases their recognition

was questionable because of the superimposed air When filled bilaterally, they were always symmetrically developed The superior posterior recess was present only on the left side in 2 cases Unilateral non filling or non recognition of these recesses is therefore a strong indication but no definite proof of pathology The lateral recesses in the a p view were well demonstrated bilaterally in 81 out of the 100 cases The filling was questionable in 7 cases A fluid level was present in the inferior part of the fourth ventricle in 3 cases out of the 12 in which these recesses were not defined The identification was made difficult in the remaining cases due to superimposition of other air filled spaces or because correct projections or a sufficient number of tomographic cuts had not been obtained The lateral recesses were evident in the lateral view in 38 cases but only in the tomograms, a low figure probably due to the fact that only one midline cut was usually obtained The velum was identifiable in the a p projection in 92 cases The fastigium was obvious only in 50 cases of the material in this projection *When not identified it was evidently projected below the anterior medullary* velum but when projected above, it was always apparent, it was invariably demonstrated in tomographic cuts through it The lateral borders of the floor were always defined The surface of the floor and the medial sulcus were never identified in this material due to the oblique inclination of the central beam These structures could always be demonstrated in the half axial projection with the central beam parallel to the floor in a limited number of cases, not included in this normal material (Figs 11, 12)

The *floor* as outlined in the lateral view forms the straight anterior border of the fourth ventricle and is continuous downwards with the canal of Magendie (Fig 7) The lateral boundaries of the floor, which correspond to the anterior *margins of the lateral walls*, are *always evident in the a p projection*, they constitute the straight boundaries of the body of the fourth ventricle, and converge upwards towards the aqueduct (Figs 8, 9, 10) The surface of the floor is *usually not defined in the a p view with the projections usually used* Any tilt of the floor may however be recognized by the position of its posterior part being assessed from evaluation of the origins of the lateral recesses The median sulcus and the median eminences, which will not have been demonstrated earlier at encephalography will always be apparent when the central ray is parallel to the floor The obex becomes evident with slightly less inclination of the head (Fig 11), its appearances were pointed out by Di Chiro (1961)

Lateral walls The superior parts of the lateral walls appear mainly in their length *in the p a projection with the central beam parallel with the anterior fossa* These constitute the straight or slightly concave boundaries of the body which appears as a pointed triangle with its apex at the aqueduct (Figs 8 9 10)

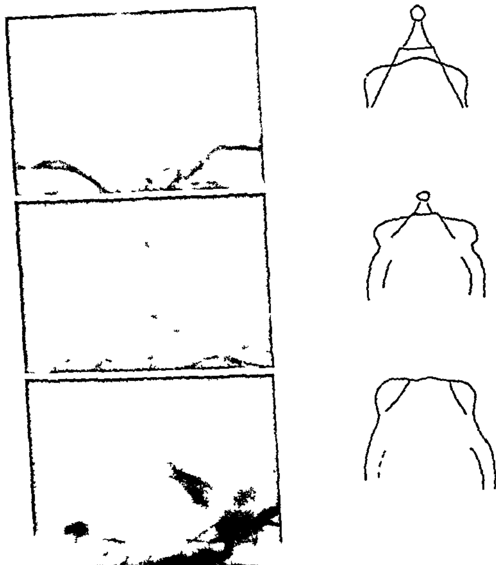


Fig 10 Ence phalography ... with explanatory drawings Influence of projection on the appearance of the fourth ventricle (Cf figs 8 and 9)

With the beam direction parallel to the floor the walls are viewed along their length and then converge slightly convex outwards for a short distance towards the anterior medullary velum The indentation of the dentate nucleus lies more inferiorly (Figs 8 9 10) and continuous posteriorly with the superior posterior

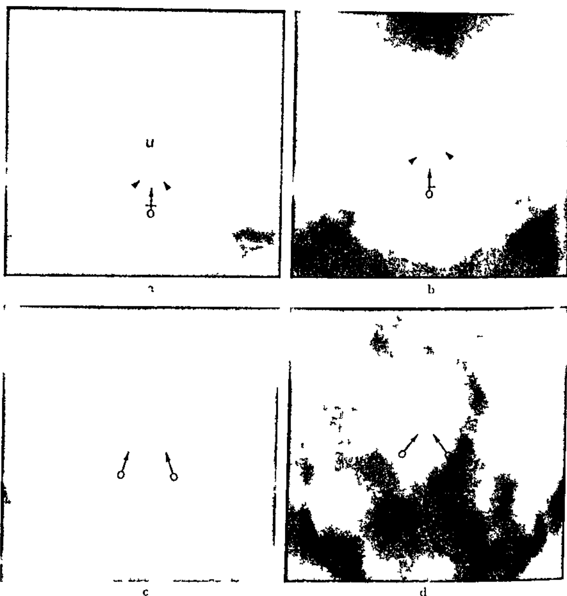


Fig. 11. Fourth ventricle. Conventional film (a) and tomographic cut (b) with the inferior margins of the floor (▶) and the obex (⟼). Uvula (u). c), d) Higher cuts include the two median eminences (o→) in d) close to the aqueduct.

recess. Inferiorly and posteriorly to the lateral recesses, the indentation of the tonsil covered by the tela chorioidea forms this part of the lateral wall and is usually revealed only in an a.p. tomogram (Fig. 13).

Roof. The velum appears as the straight or slightly upward concave boundary of the body of the fourth ventricle in the p.a. projection. This structure should be distinguished from the fastigium (Fig. 13), which is always slightly convex



Fig 12 Central ray parallel to the floor of fourth ventricle Median sulcus (⟵→) and median eminences (⟵→) These structures had not been demonstrated earlier The most superior part of the floor (▶) is projected into the body

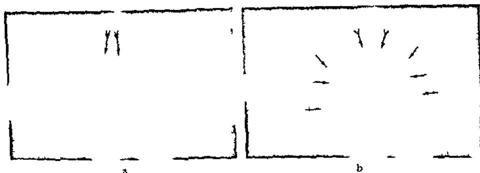


Fig 13 Tomographic cuts a) The velum (»→) with its anteriorly convex border b) The fastigium (→→) with its border convex upwards and laterally continuous with the superior posterior recesses (→) These in turn continue to the lateral recesses (→→) the beginning of which are demarcated by the indentation at the level of the anterior part of the dentate nucleus (↦→)

upwards due to the impression caused by the superior pole of the nodulus at the point where the anterior medullary velum is inserted With different inclinations, the fastigium moves with the superior posterior recesses with which it is continuous laterally (Fig 13 b) The central ray forms an angle of 20 to 30 degrees with the orbitomeatal line in the conventional a p projections The fastigium is thus usually projected below the anterior medullary velum into the body of the fourth ventricle and is partly hidden The central ray approaches a line parallel to the floor of the fourth ventricle in more axial projections and the fastigium then appears above the anterior medullary velum and the body of the fourth ventricle between and continuous with the posterior superior recesses Figs 8 9 10 Tomography is usually extremely helpful in demonstrating all these structures

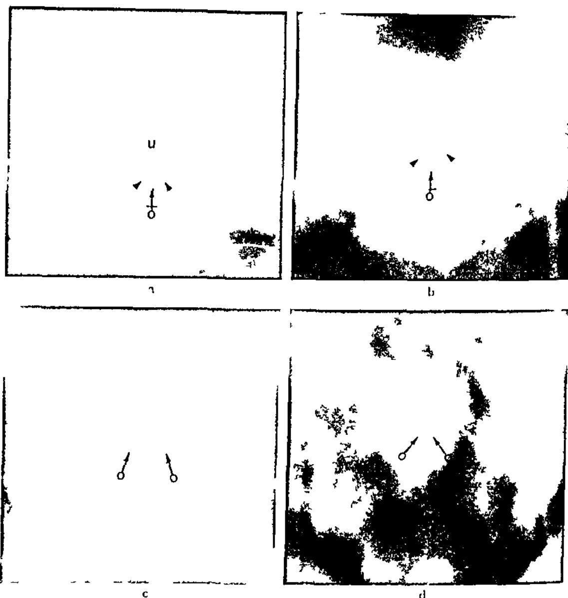


Fig 11 Fourth ventricle Conventional film (a) and tomographic cut (b) with the inferior margins of the floor (▶) and the obex (o⟶) Uvula (u) c) d) Higher cuts include the two median eminences (o→) in d) close to the aqueduct

recess Inferiorly and posteriorly to the lateral recesses, the indentation of the tonsil covered by the tela chorioidea, forms this part of the lateral wall and is usually revealed only in an a p tomogram (*Fig 13*)

Roof The velum appears as the straight or slightly upward concave boundary of the body of the fourth ventricle in the p a projection This structure should be distinguished from the fastigium (Fig 13), which is always slightly convex

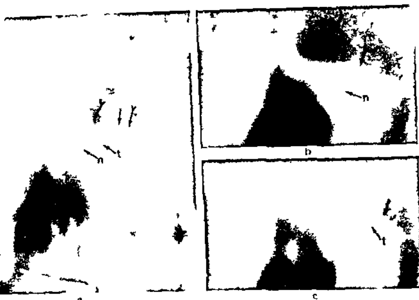


Fig 13 a) Midline zonography The fastigium (>→) and the posterior superior recess (—→) which seems to be continuous with the posterolateral fissure (»→) The indentations caused by the nodulus (n —→) and the upper poles of the tonsils (t —→) are evident b) c) Thin sagittal and parasagittal cuts in the midline with the fastigium (>→) and the nodulus (n —→) and more laterally the superior posterior recess (—→) as well as the upper pole of the tonsil (t —→)

tation reaches the floor the indentation of the nodulus is continuous inferiorly in the midline with the posterior boundary of the canal of Magendie formed by the uvula The indentations caused by the nodulus and the upper poles of the tonsils may appear in the p a projection as three areas of increased absorption in the body of the fourth ventricle their identification is almost always confined to tomography (Fig 14)

The *posterior superior recesses* appear in the lateral view as triangular extensions of the body of the fourth ventricle behind the fastigium and the indentation of the nodulus Their upper posterior border is quite straight with the inferior anterior border formed by the tonsil convex posteriorly and superiorly (Figs 7 13) they are superimposed in a true lateral view Normally they may be separated either at tomography or in conventional oblique films due to the fact that they are symmetrically developed This symmetry is also evident in the a p projection in which the recesses appear as wing like extensions of the posterior inferior part of the body (Figs 3, 8 9 10 13) They have a rounded contour and curve superiorly and laterally down to the inferior extension of the dentate nucleus which produces an indentation in the body of the fourth

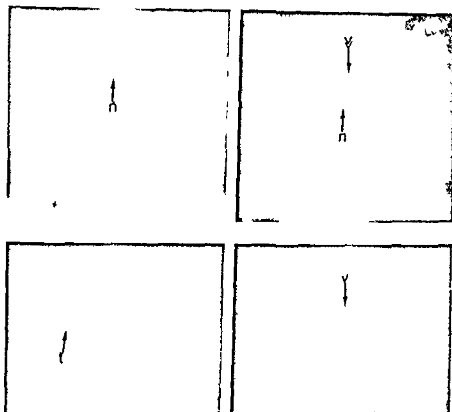


Fig 14 Conventional films and tomographic cuts The nodulus and the upper pole of the tonsils appear as indentations causing areas of increased absorption in the posterior part of the fourth ventricle The upper poles of the tonsils lie lateral to the nodulus as demonstrated in the anatomic specimen (fig 6) Again the velum (»—→) may be differentiated from the fastigium (>—→)

The components of the medial part of the roof of the fourth ventricle, i e the anterior medullary velum, the fastigium and the nodulus, as well as the more laterally located superior posterior recesses are always evident in the lateral projection (Figs 7, 15) The anterior medullary velum forms an anteriorly and inferiorly slightly convex curve that can be followed to the fastigium At this point, a small step of about 1 mm appears in the roof which inferiorly is formed by the superior posterior recesses The anterior and inferior margins of the recesses are produced by the upper poles of the tonsils, which are evident as simple or double contours, convex superiorly, and located inferiorly to the indentation of the nodulus (Fig 7) This indentation has an anteriorly and superiorly slightly convex border and may be followed superiorly and posteriorly to the point where it reaches the fastigium The tonsillar indentation on the other hand may be traced posteriorly and inferiorly to the most inferior and posterior aspect of the superior posterior recesses Anteriorly the tonsillar inden



Fig 17 a) Encephalography in vivo The cerebello medullary fissures (»←→) are filled with air and should not be confused with the lateral recesses (→→) b) These structures are also evident in central ventriculography in the cadaver Same symbols as in (a)

recess air may be present in the cerebello medullary fissure, which should not be mistaken for the lateral recess (Fig 17) Posteriorly the lateral recesses are continuous medially with the floor and laterally with the superior posterior recesses, the indentation of the dentate nucleus indicating the boundary between these two structures (Figs 3 8 9 10 13) Due to the curved shape of the lateral recesses their posterior boundaries have a more or less horizontal direction as they approach the fourth ventricle These parts are therefore more or less parallel with the central beam in the lateral view they may thus appear as an area of decreased absorption close to the floor in the most inferior portion of the fourth ventricle (Fig 7) The anterior extension of the lateral recess runs a course that is perpendicular to the floor and appears as a straight channel about 3 or 4 mm in width (Fig 7) pointing towards the foramen cecum

Acknowledgement

This work was carried out while one of the authors (M C) was on leave from the Department of Radiology Hospital de la Universidad Catolica Santiago de Chile Support was r c i d from the Gildemeister Foundation during part of this time

SUMMARY

An anatomic and radiologic investigation of the normal fourth ventricle is described This was based partly on ventriculography plastic casting and dissection combined with roentgen examination in an autopsy material and partly on observations in a normal clinical material examined by encephalography Special regard was paid to anatomic details which s f r has re e d scant attention

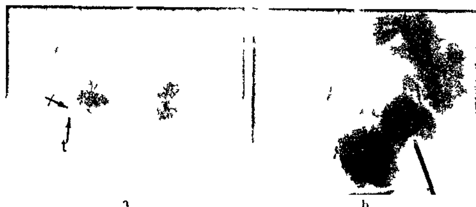


Fig 16 Roentgen examination of specimen from normal case a) The lateral recess (⟷) opens into the lateral part of the medullary cistern at the anterior border of the tonsil (t ⟶) b) Same specimen with central beam parallel to the brain stem delineating the inferior margin of the fourth ventricle and obex (o⟶) A needle points to the posterior inferior cerebellar artery within the medullary cistern

ventricle This indentation indicates the point of origin of the lateral recess (Figs 3, 8, 9, 10, 13) Medially and anteriorly the recesses are continuous with the body of the fourth ventricle without sharp demarcations, they are separated from the anterior part of the lateral wall in most a p projections

The height of the fourth ventricle as well as the distance between the fastigium and the superior posterior recesses were measured (CORRALES, unpublished) in tomographic cuts and corrected for magnification The latter measurement varied from 3 to 10 mm, the mean value being 5 0 mm The results of the height measurement were in agreement with those of AMUNDSEN et coll (1966) and OBERSON et coll (1969)

A thick cut frequently approximates the superior posterior recesses with the fastigium and the indentation of the nodulus in sagittal tomograms (Fig 15 a), with thinner cuts, they may be separated (Fig 15 b, c)

The *lateral recesses* appear in the a p projections as two symmetric channels, which are convex laterally and directed anteriorly to outline the uppermost part of the medulla before opening into the lateral part of the medullary cistern (Figs 8, 9, 10, 13, 16, 17) The medullary cistern widens and then tapers considerably in this region This local widening is called the lateral recess of the medullary system and is bounded posteriorly by the tonsil, which has an anteriorly convex border (Figs 11, 16) The boundary also indicates the most anterior extension, i e the opening of the lateral recess (Fig 16) The location and width of the opening corresponds to the lateral half of the distance between the most medial and most lateral extension of the medullary cistern Medially to the lateral



Fig 17 a) Encephalography in 1 o The cerebello-medullary fissures (»→) are filled with air and should not be confused with the lateral recesses (→) b) These structures are also evident in central ventriculography in the cadaver Same symbol as in (a)

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ZUSAMMENFASSUNG

Die Anatomie und die röntgenologische Untersuchung des *normalen vierten Ventrikels* werden beschrieben. Diese basiert teils auf der Ventrikulographie, Plastausgüssen und Dissektion kombiniert mit Röntgenuntersuchungen an einem autoptischen Material, teils auf Beobachtungen eines normalen klinischen Materials, das durch Encephalographie untersucht worden ist. Besonderer Wert ist auf anatomische Einzelheiten gelegt worden, die bislang wenig beachtet wurden.

RÉSUMÉ

Les auteurs présentent une étude anatomique et radiologique du quatrième ventricule normal. Cette étude a été basée en partie sur des ventriculographies, sur des moulages plastiques et des dissections combinées avec l'examen radiologique sur du materiel d'autopsie et en partie sur l'observation de cas cliniques normaux examinés par encephalographie. Les auteurs ont étudié particulièrement des détails anatomiques qui jusqu'à maintenant avaient peu retenu l'attention.

REFERENCES

AMUNDSEN, P. and GRIMSRUD, O. K.: Height of the fourth ventricle in normal encephalograms. Acta radiol. Diagnosis 4 (1966), 257.

AZAMBUJA, N., ARANA INIGUEZ, R., SANDE, M. T. and GARCIA GUELFI, A.: Central ventriculography. Acta neurol. lat.-amer. 2 (1956), 58.

BLAKE, J. A.: The roof and lateral recesses of the fourth ventricle, considered morphologically and embryologically. J. comp. Neurol. 10 (1900), 79.

BOCHDALEK, A.: Vierteljahrschrift für die praktische Heilkunde I, S. 119. Verlag von Borrosch und André, Prag 1849.

CORRALES, M.: The height and width of the fourth ventricle. (Unpublished.)

DAVIDOFF, L. M. and DYKE, C. G.: The normal encephalogram. Lea and Febiger, Philadelphia 1946.

DI CHIRO, G.: An atlas of detailed normal pneumoencephalographic anatomy. Charles C. Thomas, Springfield, Illinois 1961.

GREITZ, T. and GREITZ, A.: Mimer II and rotating chair. Application in neuroradiology. Elema-Schönander, Stockholm 1967.

HUANG, Y. P. and WOLF, B. S.: The vein of the lateral recess of the fourth ventricle and its tributaries. Roentgen appearance and anatomical relationships. Amer. J. Roentgenol. 101 (1967), 1.

LAST, R. J. and TOMPSETT, D. H.: Casts of the cerebral ventricles. Brit. J. Surg. 40 (1953), 525.

LINDGREN, E.: Some aspects on the technique of encephalography. Acta radiol. 31 (1949), 161.

LUSCHKA, H.: Die Adergeflechte des menschlichen Gehirnes. Druck und Verlag von Georg Reimer, Berlin 1855.

— Über die Communication der vierten Hirnhöhle mit dem Subarachnoidealraume. Z. rat. Med. 3 (1859), 68.

MAGENDIE F Recherches physiologiques et cliniques sur le liquide céphalorachidien et cérébrospinal Megnignon Marvis Paris 1842
OBERSON R Morphologie radiologique normale du quatrième ventricule insufflé Radiol Clin Biol 38 (1969) 372
— CANDARDJIS G and RAAD N Height of the fourth ventricle Acta radiol Diagnosis 9 (1969) 193
RETZIUS G Das Menschenhirn Norstedt & Soner Stockholm 1896
— Biologische Untersuchungen Neue Folge IX Verlag von Gustav Fischer Jena Afton bladets Druckerei Stockholm 1900
ROBERTSON E G Encephalography Macmillan Melbourne 1941
TWINING E Radiology of the third and fourth ventricles Brit J Radiol 12 (1939) 395 569

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EYE LENS DOSES IN CAROTID ANGIOGRAPHY

by

K. BERGSTRÖM, H. DAHLIN, MONICA GUSTAFSSON and O. NYLÉN

Only two years after the discovery of roentgen rays, CHALUPECKY (1897) reported that roentgen irradiated rabbits developed opacity of the lens of the eye fifty days after the exposure. Several authors have since given detailed descriptions of the development of so called radiation cataract in connection with radiation therapy in human subjects and experimental animals. UPTON et coll. (1953) observed lens changes in mice after an exposure of 15 R. The human lens is, however, more refractory to ionizing radiation than that of laboratory animals (UPTON et coll. 1956). MERRIAM & FOCHT (1957) reported cataracts in adults after a lens exposure of about 200 R; these authors pointed out that the lens in adults is less sensitive to radiation than in children especially infants of under one year. The latency period between a given radiation dose and the appearance of a radiation cataract varies considerably, however. With a high dose a cataract may occur within 1 to 2 months, while with a low dose this latency period may exceed 20 years.

Reports on eye lens doses in diagnostic radiographic examinations are rare. CHIN et coll. (1970) reported the cornea exposure to be about 10 R at oto tomography (16 exposures), and considered this to be possibly cataractogenic. A 2 mm thick simple lead shield reduced the exposure to about 1 R.

Submitted for publication 25 May 1971.



Fig 1 Sketch of the lens shield Scale 1 1

The number of exposures at cerebral angiography has increased considerably in recent years since the introduction of film changers No investigations of the absorbed dose to the lens of the eye at serial angiography appear to have been reported The aim of the present work was therefore to determine the size of the absorbed dose to the lens at carotid angiography and to investigate a method of reducing this by a lens shield

Material and Methods

The material consisted of 30 patients aged between 1 and 77 years The absorbed dose to the lens of the eye was measured and calculated at carotid angiography both with and without the use of a shield constructed by one of the authors (K B)

Angiographic procedure The carotid angiographies were performed according to the programme commonly used in Sweden with projections as follows lateral series of 17 films a p series I (the central beam running parallel with the floor of the anterior cranial fossa) of 12 films and a p series II (the central beam so oriented that the upper border of the pyramid was projected at the level of the lower margin of the orbit) of 8 films Exposure data for adult patients lateral series about 72 kV and 38 mAs a p series I about 92 kV and 38 mAs and a p series II about 88 kV and 38 mAs Total filtration a p tube 3 mm Al lateral tube 2 mm Al The patients always lay with the right eye nearest to the lateral tube The distance between the focus of the lateral tube and the right eye was about 76 cm and that between the focus of the a p tube and the right eye about 73 cm

Lens shield The construction of the shield appears in Fig 1 which is a sketch to scale of the shield for one eye the shield is made of plastic and lined on the inside with one mm of lead The two eye shields are attached to a rubber band which is stretched around the patient s head and thus easy to put on and take off Fig 2 depicts the shields applied for examination in the lateral projection

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EYE LENS DOSES IN CAROTID ANGIOGRAPHY

by

K. BERGSTROM, H. DAHLIN, MONICA GUSTAFSSON and O. NYLEN

Only two years after the discovery of roentgen rays, CHALUPECKY (1897) reported that roentgen irradiated rabbits developed opacity of the lens of the eye fifty days after the exposure. Several authors have since given detailed descriptions of the development of so called radiation cataract in connection with radiation therapy in human subjects and experimental animals. UPTON et coll. (1953) observed lens changes in mice after an exposure of 15 R. The human lens is, however, more refractory to ionizing radiation than that of laboratory animals (UPTON et coll. 1956). MERRIAM & FOCHT (1957) reported cataracts in adults after a lens exposure of about 200 R; these authors pointed out that the lens in adults is less sensitive to radiation than in children, especially infants of under one year. The latency period between a given radiation dose and the appearance of a radiation cataract varies considerably, however. With a high dose a cataract may occur within 1 to 2 months, while with a low dose the latency period may exceed 20 years.

Reports on eye lens doses in diagnostic radiographic examinations are rare. CHIN et coll. (1970) reported the cornea exposure to be about 10 R at otomography (16 exposures), and considered this to be possibly cataractogenic. A 2 mm thick simple lead shield reduced the exposure to about 1 R.

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and that to the centre of the lens The measured values in this report thus refer to the absorbed do e in the lens

The dosimeters consisted of LiF teflon di cs 0 4 mm thick and 12 7 mm in diameter, their ize and shape rendering them highly suitable for the measure ments The atomic numbers of LiF teflon and body tissue are o clo e that the ab orbed do e measured can be considered to apply to body tissue without correction

Ten measurements were performed in the lateral series in a p series I and in a p series II without the lens shield and 10 measurements in the lateral series and in a p eries I with the shield in place, in the total materials The measure ments in all patients were made on the right eye but in four patients measure ments were al o performed on the left eye in the lateral series in order to determine how much lower the dose was to the eye more distant to the tube The results were read with a Controls for Radiation instrument model 7 100 with a flow of nitrogen gas around the dosimeter for reduction of background effects The residual background signal was indicated by means of six dosimeters that had not undergone any form of irradiation

Every dosimeter u ed in the measurements was calibrated individually against a Farmer Secondary Standard Dosemeter with 70 kV roentgen rays (total filtration 2 mm Al) As the dosimeters were heated before (20 h at + 80 C) and after (30 min at + 80 C) the irradiation the signal read out was inde pendent of time A group of eight separate dosimeters was irradiated at the ame time as the patients with gamma radiation from a cobolt apparatus in re producible geometry This was in order to check the ensitivity variations of the dosimeters and the read out instrument between the calibration and the different measurements The standard deviation varied between 2 4 and 6 2 per cent of the mean value for each do imeter irradiated on 10 different occasions

Results

The lens absorbed doses for the right eye in the lateral projection and a p projections I and II without the lens shield are given in Table 1 The mean value for the lateral series was 5 500 mrad for a p eries I 6 900 mrad and for a p series II 4 600 mrad The mean value for the total lens absorbed dose was thus about 17 rad at carotid angiography comprising these three series The mean value per exposure was 330 mrad for the lateral series and 570 mrad for both a p series I and II

The dose values obtained when the lens shield was used are given in Table 2 The mean value for the lateral series was 620 mrad and for the a p series I 700 mrad The mean value per expo ure was 40 mrad for the lateral series and 60 mrad for a p series I The calculated lens dose was thus reduced



Fig. 2. Carotid angiography with lens shields. a) Lateral projection. b) A.p. projection I (central beam parallel with the floor of the anterior cranial fossa).

and a.p. projection I. They are not used in a.p. projection II since they would obscure parts of the carotid siphon and parts of the anterior and middle cerebral arteries.

Thermoluminescence dosimetry. The absorbed dose measurements were performed by means of thermoluminescence dosimeters applied to the upper eyelid with the patient's eyes closed. The distance between the dosimeter and the centre of the lens was calculated to be 8 to 9 mm with GULLSTRAND's (1924) model of the eye.

Measurements were performed in a head phantom. A package of dosimeters, one cm thick, was applied in the eye of the phantom. The relationship between the absorbed dose to the eyelid and the lens absorbed dose can thus be calculated according to GULLSTRAND's model. The measurements gave the following results: A.p. projection: negligible decrease of the dose from the eyelid to the centre of the lens. Lateral projection (without the lens shield): no significant difference between the dose to the lens and that to the eyelid. Lateral projection (with the lens shield): the absorbed dose in the centre of the lens was 50 per cent higher than that to the upper eyelid.

No modification of the measured absorbed dose to the upper eyelid was however performed since measurements on the new slightly modified shield (see Addendum) revealed no measurable differences between the dose to the eyelid

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Table 1

Absorbed doses in mrad at carotid angiography without lens shields. A p projection I: central beam parallel with the floor of the anterior cranial fossa. A p projection II: central beam oriented so that the upper border of the pyramid is projected at the level of the lower margin of the orbit

	Lateral proj 17 exposures	A p proj I 12 exposures	A p proj II 8 exposures
No of observations	10	10	10
Mean value	5 500	6 970	4 600
Range	4 410—7 000	5 000—8 380	3 000—5 700
Mean value/exposure	330	570	570
Range	260—410	420—700	380—720

considerably when the eye was protected by the shield. The mean value for the total lens dose was about 5.9 rad for an examination comprising the three series (including a p series II without the shield).

Discussion

Carotid angiography performed by the usual routine in Sweden thus gives a relatively high absorbed dose to the lens of the eye, on the average about 17 rad; this dose may be doubled if the examination is extended by several oblique projections. If bilateral carotid angiography is carried out in the same patient the lens dose may thus amount to 60 to 70 rad. The dose will be increased considerably, if, in the same patient vertebral angiography, encephalography, tomography and repeat examinations, for example, are also performed.

The dose was also measured at vertebral angiography in three patients in the lateral projection so as to compare the lens doses in carotid and vertebral angiography. The mean value of the absorbed dose without the shield was 17 mrad/exposure. The value is considerably lower than at carotid angiography because of the better collimation. The conditions are approximately the same as at carotid angiography for the a p projections. The absorbed dose to the lens without the shield was also measured at encephalography in a few patients. The mean value was 57 mrad/exposure to the left eye and 46 mrad/exposure to the right eye. The absorbed dose to the left eye without the shield at carotid angiography in the lateral projection was measured in 4 patients and the mean value was 42 mrad/exposure, thus about 12 per cent of the dose to the right eye, which in the investigation was closer to the tube. The lens doses must be considered in the light of the finding of lens opacities in experimental animals after an exposure of 15 R (UPTON et coll. 1953) and of cataract in adult human subjects after an exposure of 200 R (MERRIAM & FOCHT 1957).

Table 2

Absorbed doses in mrad at carotid angiography with lens shields

	Lateral proj 17 exposures	A p proj 1 12 exposures
No of observations	10	10
Mean value	670	700
Range	310 –980	470—1 060
Mean value/exposure	37	58
Range	18—58	35—88

No national or international recommendations exist for the highest permissible absorbed dose to different organs in radiographic examinations Neither are the doses in diagnostic radiography subjected to scrutiny by hospital control committees, as often happens in various radionuclide examinations For those who in their work are continuously exposed to ionizing radiation, the maximum permissible dose equivalent to the lens of the eye is 15 rem per year (ICRP 1966) Conclusions as to the maximum permissible dose for patients cannot be drawn from this recommendation The relation between the lens doses at which a cataract has occurred and those which a patient may be given is such however as to establish that the lens must be protected as adequately as possible in roentgenologic examinations of the cranial region This is especially important in examinations with a large number of exposures such as carotid angiography Such protection may be produced in a simple and effective way by the lens shield described it is easily applied and causes no discomfort It is important that the shield is of such a form that it well covers the whole lens in the lateral projection The position of the open edge of the shield was therefore determined radiographically and related to the position of the lens The shield covered the lens well and with the open edge approximately 5 to 7 mm behind its dorsal surface

The shield reduces the absorbed dose to the lens at carotid angiography to about one tenth in those projections where it can be used without obscuring the vascular regions to be evaluated Used in 2 out of 3 series at routine carotid angiography the total lens dose was reduced from about 17 to about 5 9 rad

Addendum

A new shield has now been constructed but was not used in this investigation This of essentially the same form as that described in the article is made of lead glass with a protection factor corresponding to 1 mm lead This shield will be available from Radiplast Uppsala Sweden under the name Radilens

SUMMARY

The absorbed dose to the lens of the eye at carotid angiography was investigated by thermoluminescence dosimetry and in routine serial examinations (three series) proved to be about 17 rad to the lens closest to the tube. This value is relatively high but may be reduced considerably by means of a specially constructed lens shield.

ZUSAMMENFASSUNG

Die absorbierte Dosis der Augenlinse bei der Carotisangiographie wurde mit Hilfe der Thermolumineszenzdosimetrie untersucht. Bei Routineuntersuchungen in drei Serien wurden etwa 17 rad in der Linse der dem Tubus *am nächsten lag gefunden*. Dieser Wert ist relativ hoch, kann aber wesentlich durch Verwendung eines specialkonstruierten Linsenschutzes verringert werden.

RÉSUMÉ

La dose absorbée au niveau du cristallin de l'œil a été mesurée par dosimétrie de thermoluminescence au cours de l'angiographie carotidienne en série (trois séries): cette dose est d'environ 17 rad au cristallin le plus proche du tube. Elle est relativement élevée mais peut être considérablement réduite grâce à dispositif de protection du cristallin spécialement construit.

REFERENCES

CHALUPECKY H. (a) Über die Wirkung der Röntgenstrahlen auf des Auge und die Haut. Zbl. prakt. Augenheilk. 21 (1897), 234 and 267.

— (b) Über die Wirkung der Röntgenstrahlen. Zbl. prakt. Augenheilk. 21 (1897), 386.

CHIN F. K., ANDERSEN W. B. and GILBERTSON J. D.: Radiation dose to critical organs during petrous tomography. Radiology 94 (1970), 623.

GULLSTRAND A. *In*: Helmholtz' treatise on physiological optics. Opt. Soc. Amer. I (1924), 00.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION: Recommendation of the International Commission on Radiological Protection. Publication 9. Pergamon Press, London 1966.

MERRIAM G. R. and FOCHT E. F.: A clinical study of radiation cataracts and the relationship to dose. Amer. J. Roentgenol. 77 (1957), 759.

MILNER J. G.: Irradiation cataract. Brit. J. Ophthal. 18 (1934), 497.

UPTON A. C., CHRISTENBERRY K. W. and FURTH J.: Comparison of local and systemic exposures in production of radiation cataract. Arch. Ophthal. 49 (1953), 164.

— — MELVILLE G. S. et coll.: The relative biological effectiveness of neutrons, X rays and gamma rays for the production of lens opacities. Observations on mice, rats, guinea pigs and rabbits. Radiology 67 (1956), 686.

FROM THE ROENTGEN DEPARTMENTS OF THE PEDIATRIC INSTITUTES OF POZNAN AND KRAKOW POLAND

SPONDYLO EPIPHYSEAL DYSPLASIA WITH UNUSUAL SKULL CHANGES

by

K KOZLOWSKI A BARYLAK and T NIEDZWIEDZKI

Spondylo epiphyseal dysplasias comprise a group of conditions characterised by vertebral and epiphyseal ossification disturbances Several well differentiated entities with typical clinical, genetic metabolic and radiographic changes have been isolated within the last few years although a growing number defy classification (MAROTEAUX et coll) A case of spondylo-epiphyseal dysplasia with unusual skull changes not previously associated with the condition is now reported

Case report

Pcs aged 13 normal at birth with no family history of bone disease He developed normally until his second year when genu valgum of both knees was noted At the age of four he had a car accident in which the bones of the right forearm were broken after which loss of speech as well as progressive loss of hearing occurred a year later he was compelled to wear glasses Subsequent slow mental development made it necessary for him to attend a school for mentally retarded children He had recently been referred to an ophthalmologic clinic because of partial loss of vision in the right eye retinal detachment was evident on the right side

Submitted for publication 29 March 1971

SUMMARY

The absorbed dose to the lens of the eye at carotid angiography was investigated by thermoluminescence dosimetry and in routine serial examinations (three series) proved to be about 17 rad to the lens closest to the tube. This value is relatively high but may be reduced considerably by means of a specially constructed lens shield.

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REFERENCES

CHALUPECKY, H. (a): Über die Wirkung der Röntgenstrahlen auf des Auge und die Haut. Zbl. prakt. Augenheilk. 21 (1897), 234 and 267.

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— — MELVILLE, G. S. et coll.: The relative biological effectiveness of neutrons, X rays and gamma rays for the production of lens opacities. Observations on mice, rats, guinea pigs and rabbits. Radiology 67 (1956), 686.



Fig 3 Hypertrophy of the base of the skull



Fig 4 Defective ossification of the vertebral bodies

the cortices were narrow for the subject's age the metaphyses were relatively broad *Fig 1)* Hands and feet The short bones were elongated but the epiphyseal ossification centres—especially those of the phalanges—were flattened and sclerotic The carpus was shortened *(Fig 2)* *Pelvis* The vertical diameter of the pelvis was diminished and the sacro-iliac notch decreased in size The inlet of the pelvis had an abnormal shape and



Fig. 1

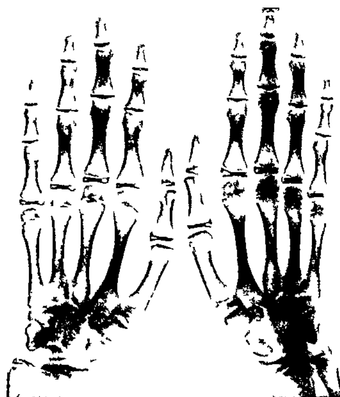


Fig. 2

Fig. 1. Left elbow. Relatively broad ends of the shafts with flattened proximal ulnar epiphyses.

Fig. 2. Hands of normal length with flattening of the epiphyseal ossification centers.

Upon admission the boy was 154 cm in height, his weight 40 kg and the circumference of his head 56 cm. The mandible appeared to be enlarged. The trunk was short with slight kyphosis, the extremities were relatively long. The elbows were prominent and knobby but the movements were normal. Genu valgum (35 to 40°) was evident and flexion of the hip joints to only 100° was possible. Bilateral talipedes equinovari were also present. Neurologic examination normal. The results of an ophthalmologic examination were as follows: Right eye: ablatio retinae totalis oculi dextri. Synechiae posteriores. Opacitates corporis vitrei oculi dextri. V: hand movements, localisation of light +. Left eye: V 6/36 C sph 16 oD. Myopic eyeground. Audiologic examination: Perceptive deafness. Hearing: Speech 0.1—0.2 m. Psychologic evaluation was impossible due to the severe hearing impairment. Hair, skin, external ears and nails were normal. Laboratory tests which included Ca, P and alkaline phosphatase levels were also normal. There was no increase in mucopolysaccharides in the urine.

Radiography. Vertebral column: Generalised platyspondylisis with irregular vertebral plates of the thoracic and lumbar vertebral bodies was present. Defective ossification of the upper and lower edges of the limbus vertebrae sup. et inf. (Fig. 4). Long bones: All the epiphyseal ossification centers were somewhat small and flattened. The shafts with



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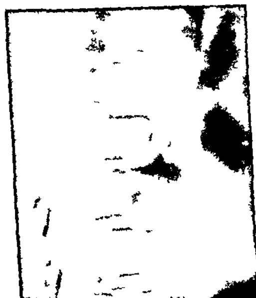


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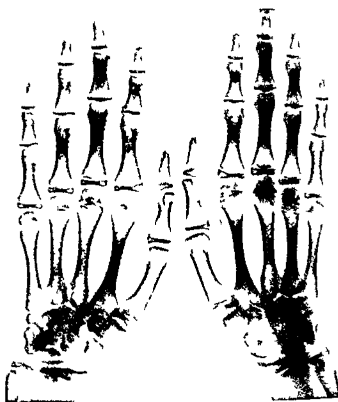


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Fig 3 Hypertrophy of the ba e of the skull

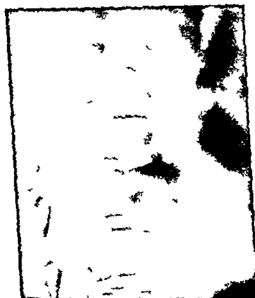


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both the pubic and ischial bones were of a heavy type, bilateral coxa valga was present and the proximal femoral ossification centers were flattened while the femoral necks were broad. Skull: The mandible was large, pointed at the lower margin anteriorly and the angle was increased. The spheno-occipital synchondrosis, the occipital condyles and the dens epistrophei were hypertrophied but the atlas was small. The sella turcica was normal although small in size (Fig. 3). Platybasia and asymmetry of the oval foramina were evident.

Discussion

Platyspondylisis and generalised or widespread flattening of the epiphyseal ossification centers are characteristic of spondylo-epiphyseal dysplasias. Changes do not often occur in the skull in this group of diseases and no record of them in spondylo-epiphyseal dysplasia can be found. LEFEBVRE apparently reported similar changes in the skull of a patient with 'polychondritis' (MAROTEAUX). The present case would appear to represent a new type of spondyloepiphyseal dysplasia typified by platyspondylisis, slight generalised epiphyseal flattening, platybasia, hypertrophy of the base of the skull and hearing impairment as well as myopia with retinal detachment.

SUMMARY

The case of a thirteen-year-old boy with spondylo-epiphyseal dysplasia and unusual bone changes at the base of the skull is described. The platybasia, increased mandibular angle with myopia and retinal detachment and hearing impairment present in this patient are discussed.

ZUSAMMENFASSUNG

Der Fall eines dreizehnjährigen Jungen mit einer spondylo-epiphysalen Dysplasie und ungewöhnlichen Knochenveränderungen der Schädelbasis wird beschrieben. Die Platybasia, der vorhandene vergrösserte Unterkieferwinkel mit Myopie und Netzhautablösung und Gehörschaden bei diesem Patienten werden besprochen.

RÉSUMÉ

Présentation du cas d'un garçon de treize ans atteint de dysplasie spondylo-épiphysaire et de lésions osseuses inhabituelles de la base du crâne. Les auteurs étudient la platybasie, l'angle mandibulaire augmenté, la myopie et le décollement de la rétine et la diminution de l'acuité auditive qui existaient chez ce malade.

REFERENCES

MAROTEAUX P. Personal communication.
— WIEDERMANN R. SPRANGER J. et coll. Essai de classification des dysplasies spondylo-épiphysaires. Simep Editeurs. Lyon 1968.

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ESTIMATION OF THE DEGREE OF AORTIC REGURGITATION BY MEANS OF DENSITOMETRY

An experimental investigation

by

M JEREB CH OLIN and L E LUNDH

A number of methods have been devised for the quantitative evaluation of aortic regurgitation these including thermo dilution and dye dilution techniques (LUTHY & RUTISHAUSER 1961 1965 LACY et coll 1959, RUTISHAUSER et coll 1962) Indicators have been injected continuously proximal to the valve and the dilution registered distally in the aorta (WOODWARD et coll 1957), the amount of regurgitant flow could be estimated from the change in the dilution curve A more direct approach has been made by introducing the indicator into the ascending aorta either in a single injection (ARMELIN et coll 1963) or in a con tinuous flow (FRANK et coll 1966) and aspiration from the ventricle Gamma ray emitting isotopes have been injected into the left ventricle and the rise and fall of the externally registered activity evaluated (HILDNER et coll 1969) Deter mination of roentgen contrast medium density in the thoracic aorta by den sitometry has also been reported (NORDENSTROM & GRIM 1965) Variations in the volume of the left ventricle have been calculated from left ventricular angio-grams and related to the measurements of the forward aortic flow by the Fick method The difference thus obtained represented the aortic regurgitation (AR VIDSSON 1961 SANDLER et coll 1963) The decline of the aortic dia tolic pressure

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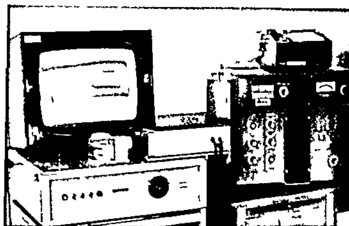


Fig. 1. The Quantimet densitometer (right) connected with a Tagarno film projector and TV monitor. Graphic recorder on top of the densitometer.

curve was found to conform to the degree of aortic regurgitation, provided the insufficiency was isolated and no interference from associated disease, such as hypertension or atheromatosis, was present (JUDGE & KENNEDY 1970). A rough estimation of the degree of aortic insufficiency may usually be made by observing the regurgitating contrast medium by cineangiography. The purpose of the present investigation was quantitatively to estimate the degree of regurgitation through the aortic valve by densitometry with a pulse duplicator and to compare the results with simultaneously performed electro-magnetic probe flow measurements downstreams in the aorta.

Equipment. The densitometer was the Quantimet Image Analysing Computer (Metals Research Ltd.). The instrument combines a TV camera with a similar unit for the automatic recording and analysis of the geometry and density of the image.

The optical image is derived from a microscope, epidiascope or, as in the present instance, a film projector, and is projected onto the screen of a television camera. The electric output from the camera is passed to a closed circuit television monitor that provides a large display image, a detector unit and thus back to the television camera so that the operator may easily check the detection operation, and to the computor. The main control is the threshold beyond which the detection takes place. A potentiometer enables a suitable visual intensity to be chosen, a polarity control allowing the detection to be made either above or below this threshold. The computer is programmed to measure, among other features, the total projected area above or below the critical visual intensity selected. The signals passing from the detector unit to the computer consist of a series of television line waveforms that give a number of rectangular pulses. The height of all pulses is constant, their lengths corresponding to the chord lengths intersected by the television lines on the features detected. The

total projected area of the features is measured by the integration of these chord pulses to give a value directly proportional to the time spent by the television scan in transversing the features detected so that it is proportional to their area

The television system employs 300 lines per field of view and the horizontal resolution gives about 10 image bits per field of view The measurements are displayed on the meter on the front of the instrument and simultaneously fed into a graphic recorder The Quantimet in its simple variety may thus be used for densitometric analysis of contrast medium quantities since both the area and the absorption level of an object may be measured at the same time The angiographic films obtained by a cineradiographic procedure, are put into a Philips Tagarno projector The image is then projected directly on the Quantimet vidicon camera which is adapted to the projector so that the image may be viewed on the monitor An area within which the measurements will be made, is then chosen and superimposed on the image this area may be varied in size and position so as to suit the object of interest as closely as possible

The amplitude of the video signal is next established by means of the potentiometer the position of which will be directly proportional to the density of the image which will be observed on the monitor screen as a bright area This is then integrated in the computer and its value as a percentage of the measuring field obtained with a detector e g graphic recorder

A pulse duplicator system (OLIN 1970) was used to test the densitometer under controlled conditions this consisted of a reservoir hydraulic pump test chamber and an elastic decompression system with test fluid

The prosthetic aortic valves (Wada Cutter and Bjork Shiley type) which in the test situation were known to provide a regurgitation of about 25 and 10 to 15 per cent respectively of the forward stroke volume were inserted in the test chamber Pressure and flow were measured distal to the valves by means of an electronic transducer (Elema) and an electromagnetic flow meter (Nycotron) and recorded by a direct writing graphic recorder (Mingograf, Elema) A teflon catheter connected to a Cial pressure injector was inserted into the aortic part of the chamber with its tip about 2 cm from the valve prosthesis The tip of the catheter was provided with both side and end openings (Fig 2)

Calculations The following calculation indicates that the volume may be measured by defining the area while varying the density by fixed steps of the potentiometer integration of the volume with the help of cylindric elements produces

$Vol_{(contr\ m\ di\ m)} = Const\ (S_1 A_1 + S_2(A_2 - A_1) + S_3(A_3 - A_2) \quad S_n(A_n - A_{n-1})$ and $Vol_{(contr\ m\ di\ m)} = (S_1 - S_2) A_1 \quad (S_2 - S_3) A_2 \quad (S_3 - S_4) A_3 \quad (S_n - S_{n-1}) A_n$ where S_n is density level for the area A_n

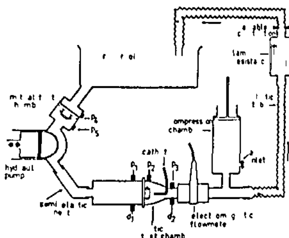


Fig. 2. The pulse duplicator system.

Since the detected density is a linear function of the position chosen for the potentiometer, the difference in the density levels ($S_n - S_{n-1}$) may be regarded as constant: Const.$_1$. The volume is then expressed as

$$\text{Vol}_{(\text{contr medium})} = CC_1\,(A_1 + A_2 + A_3 + \ldots + A_n) \text{ and}$$

$$\text{Vol}_{(\text{contr medium})} = C \sum_{1} A_n$$

This implies that each image should be measured at as many density levels as possible in order to obtain a high degree of accuracy. Six to eight levels proved for practical purposes to be satisfactory.

Calibration. The densitometer was calibrated with the same equipment later used for the experiments. A bowl containing different concentrations of contrast medium (Urografin 60 %) diluted with water to 10 to 60 per cent was filmed. The position of the potentiometer was defined for each of these concentrations by filling out the measuring field with the bright area as previously described. Kodak, type 8282, Double X, 27 DIN sensitivity film was employed with the standard Kodak Versamat Type 5 processing unit at 5 feet per second and Kodak Type 810 developer. The cineradiography was performed with a Philips

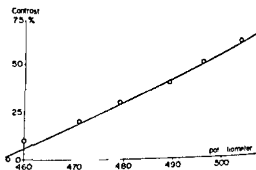


Fig. 3. Linear correlation of the concentration of the contrast medium and the position of the potentiometer.



Fig 4 Cineradiographic image of test chamber divided by valve prosthesis into the aortic and ventricular chamber A teflon catheter lies in the aortic chamber



Fig 5 Measuring area superimposed on the ventricular chamber

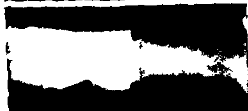


Fig 6 Measuring area superimposed on the aortic chamber

Cinepulse unit at 24 exposures per second and about 90 kV The results reveal a linear correlation of the potentiometer setting with the density of the image (Fig 3)

A sequence of the contrast medium regurgitating into the left ventricle was then selected and run in the Quantimet unit 100 times Areas under the curves were calculated the average being 8 4 cm with extreme values of 7 8 cm and 9 0 cm 79 calculated areas were within the range 8 2 to 8 6 cm

Test procedure The system was primed with water and residual air evacuated after the valve had been inserted in the test chamber of the pulse duplicator The pump was started and by varying the amount of air in the decompression chamber and adjusting the peripheral resistance the aortic pressure was set at 125/75 the stroke volume varying between 70 and 80 ml as measured by the electromagnetic flow meter When a stable mode of action had been reached 10 or 20 ml of contrast medium (Urografin 60 %) were injected under 4 to 6 kg pressure in 1 to 2 seconds and exposures made at 24 per second The conditions of exposure and processing have already been described The film was then put into the projector of the Quantimet unit A measuring field comprising most of the left ventricle and another of the same size covering the proximal aorta

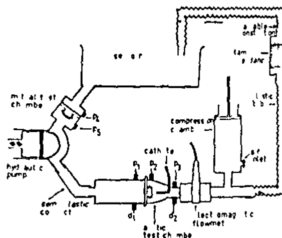


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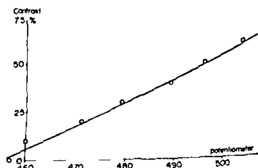


Fig 3 Linear correlation of the concentration of the contrast medium and the position of the potentiometer



Fig 8 Pressure and flow curve as registered by the flow meter The pressure curve and systolic flow above the zero line with the diastolic flow below it

Since the time of recording was constant the relation of the volume in the aorta and left ventricle during that specific time is

$$\frac{V a}{V v} = \frac{\text{Area } a \times \text{const}}{\text{Area } v \times \text{const}} = \frac{\text{Area } a}{\text{Area } v}$$

The results of measuring the aortic regurgitation in 20 cineroentgenograms of the pulse duplicator system in slightly varying conditions are presented in the Table

Discussion

There are some advantages in employing cinedensitometry in the evaluation of aortic insufficiency as compared to other methods (1) Conventional cine angiograms may be used and no special investigation procedure is required (2) the determination may be repeated by replaying the film (3) complete mixing of the contrast medium with the blood as in the indicator dilution methods, is unnecessary Cinedensitometry has the practical advantage over videodensitometry of allowing the densitometric investigations to be performed in retrospect in earlier angiographies The sources of error due to inconsistencies in the film exposure electronic transmission and processing may be disregarded in this investigation since the densities are obtained in the same film at the same exposure The measuring error in the Quantimet apparatus itself together with that of the planimetric procedure is 2 to 3 per cent under the conditions of this investigation as indicated by 100 consecutive measurements over the same sequence of films

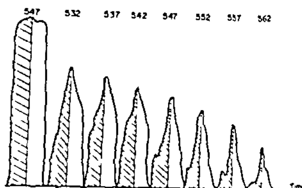


Fig 7 Seven consecutive volume registrations over the ventricular chamber at increasing levels of density One registration over the aortic chamber the shadowed areas represent diastole

were chosen, a sequence of images during the time during which the contrast medium could be detected in the left ventricle were then elected The range of the potentiometer settings was established for the image with the maximum amount of contrast medium in the left ventricle The range of the indicator was chosen in such a way that the indicator never reached 100 per cent The selected series was then run at different levels of the potentiometer as long as any contrast medium persisted in the ventricle Curves of similar shape but different heights were obtained, these representing variations in the volume of contrast medium of a given concentration with time The measuring field was next placed over the proximal aorta and the same series rerun (Figs 4, 5, 6, 7)

It soon became apparent, however, that the difference in the curves obtained over the 'aorta', was small, this was considered to be due to the higher concentration of the contrast medium in this region The sequence over the 'aorta' was therefore usually run only once, with the potentiometer set in a 'medium' position Areas were calculated by planimetry and the average arithmetic values of the different curves taken

The data obtained simultaneously by the electromagnetic flow meter were evaluated the aortic regurgitation was defined as the amount of backward flow in the aorta expressed as the percentage of the forward flow measured at the same site Planimetry of the curves was performed and the areas above and below the zero line, representing the forward and backward flows respectively, were compared (Fig 8)

Definitions Aortic regurgitation was defined as the amount of contrast medium regurgitating into the left ventricle during diastole' expressed as the percentage of contrast medium in the proximal part of the aorta' at the same time The volume of the contrast medium during the diastole in the ventricle or in the aorta may be calculated as

$$\frac{V}{t} = f(t)\,dt = \frac{\text{area under the curve}}{\text{time}}$$

SUMMARY

A method of quantitatively estimating the aortic valve regurgitation in a model by means of cinedensitometry is presented. The results correlate fairly well with those obtained by simultaneously performed electromagnetic flow measurements in the aorta.

ZUSAMMENFASSUNG

Eine Methode quantitativ die Regurgitation durch die Aortaklappe an einem Modell mit Hilfe der Cinedensitometrie zu bestimmen wird dargestellt. Die Resultate stimmen recht gut mit gleichzeitig vorgenommenen elektromagnetischen Flüssigkeitsstrommessungen in der Aorta überein.

RÉSUMÉ

Les auteurs présentent une méthode d'estimation quantitative de la regurgitation de la valvule aortique sur un modèle par cinedensimétrie. Les résultats concordent assez bien avec ceux qui ont obtenus par des mesures électromagnetiques simultanées du débit dans l'aorte.

REFERENCES

ARMELIN E, MICHAELS I, MARSHALL H W et coll: Detection and measurement of experimentally produced aortic regurgitation by means of indicator-dilution curves recorded from the left ventricle. Circulat. Res. 12 (1963) 269

ARVIDSSON H: Angiographic determination of left ventricular volume. Acta radiol. 56 (1961) 321

FRANK M J, CASANEGRA P, MANOLCHEHR N et coll: Measurement of aortic regurgitation by upstream sampling with continuous infusion of indicator. Circulation 23 (1966) 545

HILDNER F J, PIERSON W R, BAROLD S S et coll: Isotope quantitation of aortic insufficiency compared to cineangiography in man. Ann. thorac. Surg. 8 (1969) 84

JUDGE T P and KENNEDY J W: Estimation of aortic regurgitation by diastolic pulse wave analysis. Circulation 41 (1970) 659

LACY W W, GOODSON W H, WHEELER W G and NEWMAN E V: Theoretical and practical requirements for the valid measurement by indicator-dilution of regurgitant flow across incompetent valves. Circulat. Res. 7 (1959) 454

LÜTHY E und RUTISHAUSER W: Die Thermodilutionsmethode. Cardiologia 38 (1961) 183

— — SCHEU H. et coll: Farbstoff- und Kältetests in der Diagnostik der Herzklappeninsuffizienz. 31. Tagung Deutschen Gesellschaft für Kreislaufforschung p. 207 1965

NORDENSTRÖM B and GRIM S: A method of determination of blood flow with the use of roentgen contrast medium. Radiology 84 (1965) 644

OLIN Ch: Evaluation of the Kay Shiley disc valve prosthesis in the aortic position. Scand. J thorac. cardiovasc. Surg. (1970) Suppl. No 7

RUTISHAUSER W, KOHLER R, SCHEU H und LÜTHY E: Zur Bestimmung des Schweregrades der Aorteninsuffizienz mit der Farbstoffmethode. Helv. med. Acta 29 (1962) 640

SANDLER H, DODGE H T, HAY R E and RACKLEY C E: Quantitation of valvular insufficiency in man by angiocardiography. Amer. Heart J. 65 (1963) 501

TSAKIRIS A G, AMORIM D S and WOOD E H: Effect of cardiac arrhythmias on aortic valve closure studied by roentgen videodensitometry. Proc. Mayo Clin. 44 (1969) 793

WOODWARD E, PURCHELL H B and WOOD E H: Dilution curves associated with valvular regurgitation. Proc. Mayo Clin. 32 (1957) 518

Table

Results of measurements of aortic regurgitation by densitometry and electromagnetic flow meter in pulse duplicator system

Pulse rate	Amount of contrast medium	Injection pressure	Flow meter % regurg	Densitom regurg
Prosthesis I				
70/min	20 ml	2 kg	28.0	28.1
70/min	10 ml	2 kg	28.0	27.4
70/min	20 ml	2 kg	28.0	24.0
70/min	10 ml	6 kg	28.0	30.2
80/min	20 ml	2 kg	28.0	27.8
80/min	10 ml	4 kg	28.0	25.0
80/min	20 ml	6 kg	28.6	28.8
88/min	20 ml	2 kg	29.0	27.0
88/min	20 ml	5 kg	29.0	25.0
88/min	20 ml	6 kg	29.0	26.0
Prosthesis II				
88/min	20 ml	2 kg	16.1	15.8
88/min	10 ml	4 kg	16.1	15.8
80/min	20 ml	4 kg	16.2	16.1
80/min	20 ml	5 kg	16.2	17.5
80/min	20 ml	6 kg	16.2	16.5
80/min	10 ml	6 kg	16.2	18.5
80/min	10 ml	4 kg	16.2	16.4
70/min	20 ml	6 kg	17.5	18.4
70/min	10 ml	6 kg	17.5	16.7
70/min	20 ml	2 kg	17.5	17.1

The measuring area often failed to encompass all of the contrast medium. This especially occurred in the aorta, where the contrast medium moved away from the valves under the injection, even in diastole. Most of it, however, was always in the measuring field and its highest concentration usually close to the valves.

The time of the injection was longer than a cycle of the pulse duplicator. A pure diastolic injection could thus not be achieved: the systolic part of the volume curve of the aorta reflected even the increase in concentration due to the continuing injection of the contrast medium, so that the systolic part of the cycle was disregarded in the calculations of the regurgitation. Another reason for this was, of course, the fact that the systolic ejection of the contrast medium from the left ventricle depends on factors other than incompetent valves.



Fig 1 Case 1 Slightly enlarged heart with a bulge along the left border superiorly indicating corrected transposition of the great vessels

Three cases of supracristal ventricular septal defects in congenitally corrected transposition are now presented anomalies that appear not to have been reported previously These were collected from a series of 15 cases of corrected transposition of the great vessels examined by cinecardioangiography in recent years

Case reports

Case 1 A 5 year-old boy was admitted for re assessment and possible surgery of complicating lesions associated with his corrected transposition of the great vessels The diagnosis had been established in 1967 At two to three months of age cyanosis had been noted and in the past six months the boy had complained of extreme fatigue and chest pain with increasing cyanosis especially on exertion Physical examination revealed cyanosis at rest and clubbing of the fingers and toes The first heart sound was normal the second was loud and single A pansystolic murmur as well as a possible second basal systolic ejection murmur were heard all over the precordium The ECG indicated biventricular hypertrophy with prominent posterior forces Roentgenography of the chest indicated that the heart was normal in size or that both ventricles were slightly enlarged and a bulge in the left border of the heart superiorly was compatible with the diagnosis of corrected transposition of the great vessels (Fig 1)

The findings at cardiac catheterization indicated small left to right and small right to-left shunt at the ventricular level The pressures in the two ventricles were equal at the systemic level (100/4 mm Hg) a gradient of 80 mm was recorded across the pulmonary valve and normal pressure of the pulmonary artery (16/10 mm Hg)

On cardioangiography a smooth walled chamber was outlined and morphologically appeared to be a left ventricle The pulmonary artery arose from the posterior part of this ventricle the anterior superior part of the left ventricle had a shelf like appearance

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SUPRACRISTAL VENTRICULAR SEPTAL DEFECTS IN CONGENITALLY CORRECTED TRANSPOSITION OF THE GREAT VESSELS

by

H. BOGREN and L. CARLSSON

Corrected transposition of the great vessels is a rare congenital malformation characterized by ventricular inversion and associated reversal of the position of the orifices of the aorta and the pulmonary artery. Intracardiac anomalies are usually present, the most common complicating lesions being ventricular septal defect, atrioventricular conduction disturbances, obstruction to the pulmonary outflow tract, and anomalies of the systemic atrioventricular valve (ANDERSON et coll. 1957, BECK et coll. 1961, CAREY & RUTTENBERG 1964, ELLIS et coll. 1962, HALLMAN et coll. 1967, HONEY 1963, SCHIEBLER et coll. 1961, SHAHER 1964, WATSON 1964).

Recognition of corrected transposition and associated lesions is important now that surgical treatment has become increasingly available. A detailed preoperative diagnosis is essential, since operation on hearts with corrected transposition is associated with high morbidity and mortality rates.

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Fig 3 Case 2 Frontal cineaortogram A left sided ascending aorta forms the left border of the cardiac outline superiorly

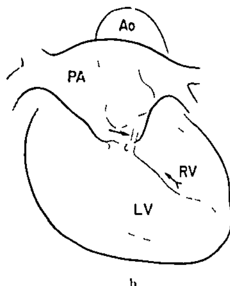
Case 2 An 8 year-old girl was admitted for re assessment of a cardiac lesion Corrected transposition of the great vessels had been diagnosed three and five years earlier A heart murmur but no cyanosis had been present at the age of two weeks epi odes of apnea and cyanosis at nine months had been noted The child did well until the age of five years when lassitude and cyanosis commenced to increase

The patient appeared to be a normally developed girl with mild cyanosis and possible clubbing of the fingers The first heart ound was normal the second sound being narrow ly split or single and best heard at the left sternal border superiorly a holosystolic plateau shaped murmur was present below with a late peaked higher pitched murmur above at th same border The ECG disclosed deviation of the right axis and right ventricular hypertrophy Roentgenograms of the heart indicated slight enlargement with a prominent left shoulder superiorly probably representing a left sided ascending aorta as in corrected transposition The pulmonary vessels appeared normal or slightly dilated

The oxygen saturation at cardiac catheterization was increased slightly between the right atrium and the venous ventricle but wa slightly decreased in the ascending and descending aorta compared to that of the systemic ventricle A left to-right shunt of 0 61/min and a right to-left shunt of 1 41/min were calculated the ratio of pulmonary systemic flow was 0 8 1 with normal pulmonary flow and slightly increased systemic flow The ventricular pressures were equal at the systemic level The pulmonary artery could not be entered Aortography revealed a transposed anterior and left sided aorta at the left border of the h art as in corrected transposition (Fig 3) The aorta arose from a trabeculated posterior anatomic right ventricle Th contrast medium flowed bidirectionally through a large in fracristal ventricular septal defect The anterior smooth walled anatomic left ventricle had a characteristic shelf with a pulmonary artery arising posteriorly A small channel like



a



b

Fig 2 Case 1 a) Lateral cineangiogram and b) plan sketch of cineangiogram of the anterior ventricle with corrected transposition of the great vessels with one supracristal (→) and one infracristal ventricular septal defect (>→) The aorta is placed medially and the left pulmonary artery superimposed on the left border of the heart superiorly

characteristic of corrected transposition The contrast medium flowed bidirectionally through two ventricular septal defects one of which connected the bodies of the two ventricles The second defect joined the anterior superior part (the shelf) of the anatomic left ventricle and the outflow tract of the posterior right ventricle (Fig 2 a) The two defects represented one infracristal and one supracristal ventricular septal defect The subpulmonary area was obstructed by thick tissue which ballooned cephalad during systole The angiogram of the posterior ventricle outlined a trabeculated myocardium and an infundibulum joined to the anteriorly placed aorta a left superior vena cava communicated with the coronary sinus The left border of the heart superiorly was not formed by the ascending aorta but rather by the left pulmonary artery The ascending aorta lay more medially (Fig 1 2 b) Diagnoses Corrected transposition of the great vessels one infracristal and one supracristal ventricular septal defect subpulmonic stenosis persistent left superior vena cava

Two days following cardioangiography the patient underwent surgical correction of the defects Loose fibrous tissue was causing the subpulmonary stenosis and the infracristal and supracristal defects were identified the excessive fibrous tissue (redundant valve tissue) was trimmed off and the remainder used to construct a flap over the infracristal defect The supracristal defect and the left superior vena cava were tied off The patient is now in excellent condition

the other two cases (Fig 5) The defect was outlined following injection of contrast medium into the venous and arterial ventricles The shunt was too small to influence the oxygen saturations in the ventricles the ascending aorta was medially situated and failed to form the left upper border of the heart which in this patient as well was represented by the left pulmonary artery

Discussion

The supracristal defect in Case 1 was recorded at the first investigation in 1968 and was still present at a recent second cinecardioangiographic examination The diagnosis was confirmed at operation when the defect was located and closed the associated lesions being repaired at the same time The defect in Case 2 had been misinterpreted originally Large infracristal ventricular septal defects were also present in all 3 cases with a supracristal ventricular septal defect A small channel like structure was situated anteriorly in 2 other cases whether this represented a true supracristal ventricular septal defect could not be determined The frequency of a supracristal defect in the series of at least 20 per cent consequently implies that the defect is probably common and should always be sought for in this cardiovascular condition now that it is amenable to corrective surgery The defect in Case 1 was large enough to assume hemodynamic importance in the other two cases it was small but should nevertheless be corrected at any future operation because of the risk of ensuing bacterial endocarditis

The ascending aorta was situated more medially than usual in corrected transposition in Cases 1 and 3 it is generally left sided and projects at the upper left border of the heart The left pulmonary artery was superimposed on this border (Figs 1 2 b) in these 2 cases in the other cases including Case 2 the aorta formed the border (Fig 3) The right upper outline of the heart in a case of dextrocardia and corrected transposition was produced by the ascending aorta Whether the coincidence of a medially situated aorta in corrected transposition and a supracristal ventricular septal defect is of embryologic or pathogenic significance is not known The supracristal as well as the infracristal defects are compatible with the hypothesis of GRANT (1964) of the morphogenesis of corrected transposition as both are probably produced simultaneously during fetal life GRANT suggested that corrected transposition and ventricular septal defect develop at the same time The association of several types of ventricular septal defects with corrected transposition is therefore not surprising

Acknowledgement

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Fig. 4



Fig. 5a



Fig. 5b

Fig. 4. Case 2. Lateral arterial cineventriculogram. A small channel-like supracristal ventricular septal defect (→).

Fig. 5. Case 3. a) and b) Lateral cineangiogram with injection into the arterial ventricle. Variable size of a supracristal ventricular septal defect (→).

supracristal defect between the antero-superior part of this venous ventricle and the outflow tract of the arterial ventricle and the large infracristal defect were both filled (Fig. 4). This was a case of corrected transposition of the great vessels with two ventricular septal defects, one large infracristal and one small supracristal, together with pulmonary stenosis of an undetermined degree.

Case 3. A 10 1/2 year old boy was admitted for re-assessment of a cardiac lesion. A murmur had been noted at birth but the child had been free of significant cardio-respiratory signs. A few episodes in which perioral cyanosis and deep tachypnea following prolonged exertion had occurred were described. Incomplete cardiac catheterization and cardioangiography at five years of age had revealed corrected transposition of the great vessels but the diagnosis was inconclusive as regard associated lesions. Physical examination revealed a healthy child with a grade 3/6 somewhat harsh systolic ejection murmur followed by an inconstant and faint high-pitched short diastolic murmur at the second left interspace. Roentgenograms of the chest indicated normal heart size and pulmonary vasculature. Some straightening of the upper left border was believed to represent the ascending aorta on the left side, consistent with the diagnosis of corrected transposition.

Cardiac catheterization revealed pressures in the venous and arterial ventricles of 45/11 and 97/17 mm Hg respectively. The oxygen saturations was 82 and 95 per cent in the venous and arterial ventricles, 82 per cent in the right atrium and 95 per cent in the ascending aorta. A cineangiogram recorded corrected transposition of the great vessels and an anomalous pulmonary venous return from the left upper lobe to the left innominate vein. A small communication, variable in size during the cardiac cycle, between the venous ventricle and the outflow tract of the arterial ventricle represented a supracristal ventricular septal defect. The appearances of the defect were similar to those demonstrated in

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DEXTROCARDIA IN GREENLAND

by

G RØNN and S ANDERSEN

Dextrocardia is the term used to indicate location of the heart in the right hemithorax with the apex pointing to the right occurring with accompanying transposition of the abdominal viscera or without such transposition WELSH & FELSON (1956) classified dextrocardia more fully as follows (1) Dextrocardia with complete transposition of viscera also termed situs inversus totalis (2) Dextrocardia without transposition of other organs but with inversion of the ventricles that may be complete and then called situs inversus partialis The cause is malrotation of the primary heart rudiment two weeks following fertilization of the ovum (3) Dextrocardia without transposition of organs and without inversion of the ventricles a condition termed dextroversion and produced by anticlockwise rotation of the heart in the sixth fetal week (4) Dextrocardia caused by factors outside the heart e g right sided pulmonary anomalies and thoracic deformities referred to as dextropositio cordis

Situs inversus partialis and dextroversion of the heart may be accompanied by other congenital cardiac anomalies (JOHNSON 1949) a familial occurrence of

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SUMMARY

Three cases of supracristal ventricular septal defect as an accompanying lesion to corrected transposition of the great vessels are described. A larger infracristal defect was also present. The frequency of supracristal ventricular septal defects in the series was at least 20 per cent. The importance of identifying all complicating lesions in corrected transpositions, which may now be corrected surgically, is stressed.

ZUSAMMENFASSUNG

Drei Fälle eines supracristalen Ventrikelseptumdefekts als Begleitschaden bei der Korrektur der Transposition der grossen Gefässe wird beschrieben. Es wird ferner ein grösserer infracristal gelegener Defekt dargestellt. Die Frequenz der supracristalen Ventrikelseptumdefekte betrug in der Serie mindestens 20 Prozent. Die Bedeutung, alle komplizierenden Schädigungen bei korrigierten Transpositionen zu identifizieren, die jetzt chirurgisch korrigiert werden können, wird hervorgehoben.

RÉSUMÉ

Présentation de 3 cas de communication interventriculaire sus-wolfienne accompagnant une transposition corrigée des gros vaisseaux. Il y avait aussi une communication sous-wolfienne plus large. La fréquence des communications interventriculaires sus-wolfiennes dans cette série était d'au moins 20 pour cent. Les auteurs insistent sur l'importance qu'il y a à identifier toutes les lésions qui compliquent les transpositions corrigées et qui peuvent maintenant être corrigées chirurgicalement.

REFERENCES

ANDERSON, R. C., LILLEHEI, C. W. and LESTER, R. G.: Corrected transposition of the great vessels of the heart. Pediatrics 20 (1957), 626.

BECK, W., SCHRIRE, V., VOGELPOEL, L. et coll.: Corrected transposition of the great vessels. Brit. Heart J. 23 (1961), 497.

CAREY, L. S. and RUTTENBERG, H. D.: Roentgenographic features of congenital corrected transposition of the great vessels. A comparative study of 33 cases with a roentgenographic classification based on the associated malformations and hemodynamic states. Amer. J. Roentgenol. 92 (1964), 623.

ELLIS, K., MORGAN, B. C., BLUMENTHAL, S. and ANDERSEN, D. H.: Congenitally corrected transposition of the great vessels. Radiology 79 (1962), 35.

GRANT, R. P.: The morphogenesis of corrected transposition and other anomalies of cardiac polarity. Circulation 29 (1964), 71.

HALLMAN, G. L., GILL, S. S., BLOODWELL, R. D. et coll.: Surgical treatment of cardiac defects associated with corrected transposition of the great vessels. Circulation 35 (1967), Suppl. No. 1, p. 133.

HONEY, M.: The diagnosis of corrected transposition of the great vessels. Brit. Heart J. 25 (1963), 313.

SCHIEBLER, G. L., EDWARDS, J. E., BURCHELL, H. B. et coll.: Congenital corrected transposition of the great vessels: a study of 33 cases. Pediatrics 27 (1961), Suppl. No. 849.

SHAHER, R. M.: The syndromes of corrected transposition of the great vessels. Brit. Heart J. 25 (1963), 431.

WATSON, G. H.: The diagnosis of corrected transposition of the great vessels. Brit. Heart J. 26 (1964), 770.

REFERENCES

HARVARD B and HELS J The incidence of cardiac malformation in Greenlandic eskimos Acta med scand 185 (1969) 41

HOLM M HOLM S and WINGE M Second part of mass-examination for tuberculosis of the municipality of Copenhagen 1947/48 Acta tuberc scand 24 (1950) 182

JOHNSON J R Situs inversus with associated abnormalities Arch Surg 58 (1949) 149

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transposed viscera in Norway has been mentioned by THORGERSEN (1946). More recent classifications are those put forward by VAN PRAAGH et coll. (1964), STANGER et coll. (1968) and LEV et coll. (1968) in which due account was given to the mechanism of evolution of the various types of dextrocardia.

HOLM et coll. (1950) reported 12 men and 6 women with situs inversus, i.e. 0.09 per thousand in a mass radiography survey of tuberculosis of 191 204 inhabitants of Copenhagen in 1947—48. KREBS LANGE (1963) mentioned in passing that situs inversus occurs fairly frequently in Greenland.

Material and Results. The present material originates from a mass radiography survey of tuberculosis on the west coast of Greenland. The survey has been made annually since 1955 by means of the radiography ship 'Misigssut' and, including 1968, a total of about 50 000 subjects have been examined, approximately 38 000 Greenlanders and 12 000 Danes. These represented practically the whole of the West Greenland population, including that of the Thule district. A review of their record cards revealed 11 with dextrocardia (7 men and 4 women), all these were Greenlanders. The frequency of dextrocardia in Greenlanders is thus 0.29 per thousand, i.e. more than three times that reported by HOLM et coll. (1950) in the Copenhagen population. No familial occurrence could be proved and no attempt was made to classify the dextrocardias discovered. It is probably reasonable to assume that the larger frequency of dextrocardia in Greenlanders may be racially conditioned. HARVALD & HELS (1969) reported that the frequency of congenital heart malformations in Greenlanders is the highest registered in any population group.

SUMMARY

A mass radiography survey of tuberculosis included 38 000 West Greenlanders, 11 of whom had dextrocardia, i.e. 0.29 per thousand. No classification was attempted.

ZUSAMMENFASSUNG

Bei einer allgemeinen Massenröntgenuntersuchung hinsichtlich Tuberkulose bei der 38 000 Bewohner von Westgrönland untersucht wurden, fanden sich 11 mit Dextrocardie, d. h. 0.29 per Tausend. Es wurde keine Klassifikation versucht.

RÉSUMÉ

Une campagne de dépistage radiographique systématique de tuberculose pulmonaire a touché 38 000 Groenlandais de l'Ouest, dont 11 avaient une dextrocardie, c'est à dire 0.29 pour mille. Les auteurs n'ont pas tenté d'établir une classification de ces anomalies.

REFERENCES

HARVARD B and HELS J The incidence of cardiac malformation in Greenlandic eskimos Acta med scand 185 (1969) 41

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR: PROF. O. OLSSON),
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ANGIOGRAPHY IN THE DIAGNOSIS OF DUODENAL LESIONS

II. Benign tumours, ulceration and inflammatory and vascular lesions

by

OLLE OLSSON

A common differential diagnostic difficulty presented by primary carcinoma of the duodenum and carcinoma of the head of the pancreas in certain ulcerative, infiltrative or stenotic lesions of the duodenum has been considered in previous papers (OLSSON 1968, 1971). Many other conditions must however also be included. SALIK (1961), for example, discussed various abnormalities simulating duodenal changes in carcinoma of the head of the pancreas and BOSSE & NEELY (1969) dealt with the matter on a wider basis. The authors agreed on the difficulty in many instances of arriving at a definite diagnosis both as to the primary site of a tumour and its malignancy.

Further progress in differential diagnosis is obviously needed. Previous papers on the angiographic features of primary duodenal carcinoma (OLSSON 1968, 1971) and carcinoma of the pancreas affecting the duodenum (OLSSON 1971) suggested that the differential diagnosis was obtainable by angiography. It was anticipated that this would be a useful tool in the diagnosis of lesions in or involving the duodenum such as malignant and benign tumours, ulceration, inflammation or vascular changes.

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Fig 1 Case 1 Duodenal ulcer a) Large ulceration in second part of duodenum b Angiography No changes evident

A number of such lesions representing differential diagnostic problems will be discussed with reference to cases in an earlier paper (OLSSON 1971) and in part I of this work (OLSSON 1972) on the differentiation between primary duodenal carcinoma and carcinoma of the pancreas with involvement of the duodenum This will enable a comparison to be made with corresponding changes in the different segments of the duodenum as presented in these previous papers

Case reports

Duodenal ulcer

Case 1 (Fig 1 Male aged 48 with ulceration of the second part of the duodenum The localization of the lesion its appearances and the symptoms of continuous and severe pain suggested that the ulceration might be malignant and associated with duodenal or pancreatic carcinoma Combined celiac and superior mesenteric angiography revealed no evidence of malignancy this was confirmed at operation and by pathology

The findings at roentgen examination should be compared with those in Case 3 OLSSON (1971)

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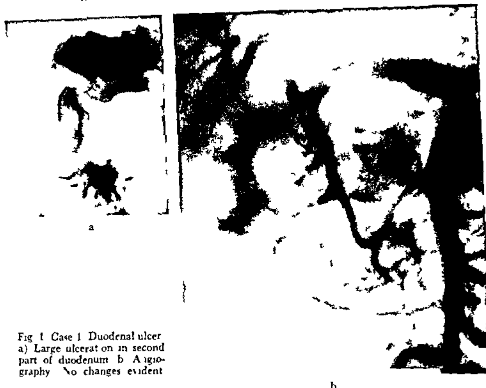


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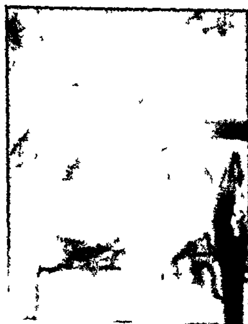
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F Case 3 Regi nal enteritis a) Marked ch an es in first and econd parts of duodenum b) Angiography Increased va cu larity w h rapid art rio enous flo

a





b

and many veins in and around the ulceration were filled The vascular changes were of a type quite different from those in primary duodenal carcinoma Operation Deep callous ulcer confirmed by pathology

This case should be compared with Case 1 OLSSON (1971) and Case 1 part I



a

Fig 2 Case 2 Duodenal ulcer a) Large irregular ulceration in duodenal cap (resistant to conservative treatment) b) Angiography Wide and tortuous duodenal branches directed laterally to gastroduodenal artery Well filled capillaries large veins No tumour vessels and no vascular changes



b

Angiography indicated by a suggestion of the duodenal ulceration being part of a tumour of the pancreas has sometimes disclosed increased vascularization in the duodenum marked localized changes occurred at angiography in one case

Case 2 (Fig 2) Male aged 65 who had been operated upon one year previously for hiatus hernia with severe pain in the upper part of the abdomen A barium meal disclosed a large irregular area of ulceration in the duodenal cap Its shape size and resistance to conservative therapy for two months suggested malignancy At celiac angiography the gastroduodenal artery was normal but the lateral duodenal branches were wide and tortuous The capillary bed in the area of ulceration and its surroundings was considerable



Fi 4 Case 4 Leiomyoma a) Well de fined tumour at duoden jejunal flexure b) An iography Tumour r ch in vessels ch a teristic f leiomyoma

a





b

Case 5 (Fig 5) Male aged 71 with intermittent melaena was referred with the diagnosis of carcinoma of the head of the pancreas Combined celiac and superior *mesen* teric angiography disclosed a richly vascularized tumour in the duodenum suggestive of a leiomyoma pancreas normal Confirmed at operation and by pathology

Regional enteritis

It is well known that regional enteritis may exceptionally be localized exclusively to the duodenum (see, for example NELSON 1969). The findings at conventional examination are usually fairly characteristic although other conditions may produce similar changes. Two patients had angiographic appearances in the duodenum corresponding to those evident in regional enteritis elsewhere, as described by LUNDERQUIST et coll. The following is an illustrative case.

Case 3 (Fig. 3). Female aged 28 with increasing pain in the upper part of the abdomen for a year. A barium meal disclosed ulceration of the duodenum but a repeat examination no ulcer but narrowing in the first and second parts of the duodenum. A possible Zollinger-Ellison tumour in the pancreas indicated angiography. Combined celiac and superior mesenteric angiography. No growth of the pancreas. Increased vascularity of the duodenum with rapid arterio-venous flow was evident. Operation revealed regional enteritis (Crohn's disease), confirmed by pathology.

The angiographic changes in this, as in the other case of regional enteritis, were easily distinguishable from those in primary or secondary malignancy of the duodenum.

Mention should be made in this connection of other types of duodenal changes evident in connection with ulcerogenic tumour (ZBORALSKE & AMBERG 1968) with the exception of ulceration as referred to above. Angiographic examination of such patients in whom an ulcerogenic tumour was considered probable but not confirmed revealed either normal conditions or hypervascularity of the duodenum.

Benign tumours

A few patients with polyps of the duodenum have been examined angiographically without changes being detected. An insuloma embedded in the duodenal wall was defined in a barium meal in one patient. Angiography proved this to be rich in capillaries so that the growth was demonstrable during a long capillary phase. Another neoplasm was embedded in the pancreas. Illustrations appear in figure 3 of a paper by BOIJSEN & SAMUELSSON (1969). The lesion evident at angiography bore no resemblance to carcinoma.

The author has examined a number of patients with leiomyoma in which the angiographic appearances seem to be characteristic and very different from those encountered in carcinoma. The following are examples.

Case 4 (Fig. 4). Male aged 67 with melaena in whom roentgen examination of the alimentary tract revealed a 5 cm × 3 cm well defined tumour at the duodenojejunal flexure. Angiography of the superior mesenteric artery demonstrated that the growth was rich in vessels and doubtless a leiomyoma; this was confirmed at operation and by pathology.

One particular case is especially interesting as a barium meal indicated that the changes were those usually present with a growth in the head of the pancreas and considered characteristic of such



a



b

Fig 6 Case 6 Vascular malformation a) Peripapillary changes in second part of duodenum suggesting enlargement of head of pancreas b Angiograph Stenosis of celiac artery and post tenotic dilatation Widening of gastroduodenal artery and pancreaticoduodenal arcades and their branches in the region of head of pancreas

Aneurysms or tortuous arteries by pressure or by bleeding may cause duodenal changes (BRUWER & HALLENBECK 1957 GUIDA & MOORE 1966 SWEETMAN & WEINSTEIN 1966 MCEWAN ALVARADO et coll 1967) The conditions reported were established only at operation The following is an example of an angiographic diagnosis in such a condition

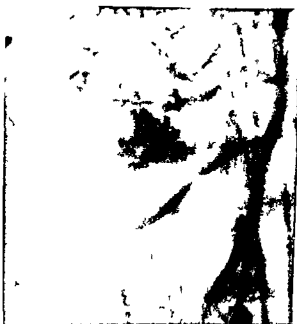
Case 6 Fig 6) Male aged 70 with probable malignant disease A barium meal examination disclosed a small defect in the first part of the duodenum A filling defect was evident around the papilla of Vater suggesting a growth in the head of the pancreas Combined celiac and superior mesenteric angiography Stenosis of the celiac artery with post stenotic dilatation and widening of the gastroduodenal artery and of the pancreaticoduodenal arcades in the walls of which calcifications were evident The common hepatic artery was in the form of a fusiform aneurysm with a diameter of up to 24 mm Tortuous collateral arteries were present in the region of the head of the pancreas The aneurysm and the wide and tortuous collateral arteries corresponded to impressions in the duodenum as seen at barium examination The vascular abnormalities were characteristic and explained the duodenal changes

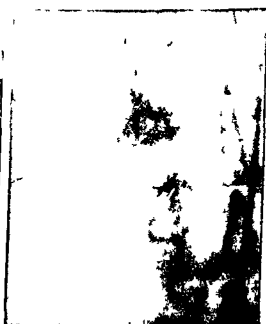
The vascular nature of the lesion was less obvious in another patient



a

Fig. 5. Case 5. Leiomyoma. a) Duodenal changes in peripapillary region suggesting enlargement of head of pancreas. b) Angiography. Leiomyoma in duodenal wall. No pancreatic tumour.





b

localization shape and size and for primary duodenal carcinoma, regional enteritis and probably other inflammatory lesions such as tuberculosis may also be difficult to identify It is also true of vascular changes with or without bleeding and for secondary changes produced by haemorrhage

Pathologic processes involving the duodenum secondarily add to the differential diagnostic problems Carcinoma of the pancreas thus sometimes encroaches upon the duodenum in other parts than at the papilla of Vater On the other hand varying pathologic processes such as benign growths of the duodenum and vascular changes around the duodenum may cause changes similar to those produced by enlargements of the head of the pancreas This is illustrated in the present cases and in the case reports accompanying previous papers in this series on primary duodenal carcinoma (OLSSON 1971) and carcinoma of the pancreas involving the duodenum in an atypical fashion (part I) The differential diagnosis must thus include in addition to ulcer, primary duodenal carcinoma and carcinoma of the pancreas when the former is of unusual localization or size and shape or runs an atypical clinical course (Cases 1 and 3 in OLSSON (1971) Case 1 in part I and the present Cases 1 and 2)

Changes produced by primary duodenal carcinoma carcinoma of the pancreas and stenosis from scar formation following haemorrhage may present the same roentgen appearances (Cases 4 and 5 in OLSSON (1971), Cases 2 4 and 5 in part I and the present Case 7) Atypical or less characteristic signs in the duodenum may also be difficult to define (Case 1 in OLSSON (1971) and the present Cases 2 and 3) Changes in the duodenum at barium meal examination suggestive of enlargement of the head of the pancreas may, as in Case 5, be caused for instance by a leiomyoma in the duodenal wall or as in Case 6, by a vascular malformation A differential diagnosis could be made by angiography in all the lesions mentioned The vascular supply of the duodenum and the head of the pancreas are to some degree common but the varying involvement of the arterial system in the different types of tumour makes differential diagnosis possible In addition malignancy may often be excluded and a benign growth detected Surgical exploration has been necessary to date to evaluate cases of this type Angiography should now make it possible to avoid such intervention or at least indicate the line of surgical approach

SUMMARY

Completely different types of lesions of the duodenum may produce changes indistinguishable from one another at conventional barium meal examinations The role of angiography in the differential diagnostic possibilities is discussed with reference to 7 selected cases

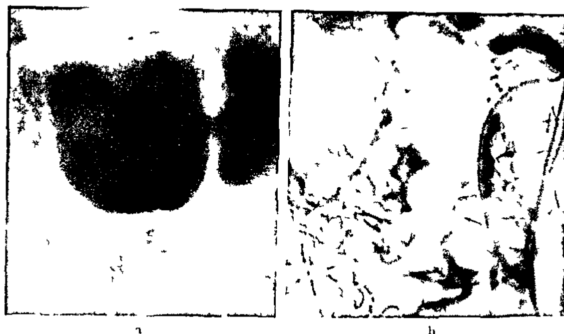


Fig. 7. Case 7. Aneurysm in lower pancreaticoduodenal arcade (previous bleeding). a) Dilatation of duodenum down to third part, the site of stenosis. b) Angiography. Aneurysm (→) 6 mm × 10 mm in irregular, widened lower gastroduodenal arcade corresponding to duodenal stenosis. No bleeding.

Case 7 (Fig. 7). Male, aged 63, with ten days abdominal pain, had undergone laparotomy for acute appendicitis; operation revealed only a hematoma in the mesentery of the small bowel. The patient made an uneventful recovery but later developed increasing vomiting. Dilatation of the stomach and duodenum was disclosed by barium meal examination. An area of partial stenosis was evident in the distal part of the second part of the duodenum, the nature of which could not be determined. Angiography of the celiac and superior mesenteric artery: Stenosis of the celiac artery with a small aneurysm of a branch of the hepatic artery with slight atheromatosis proximally in some branches to the small intestine. The lower pancreaticoduodenal arcade was wide and tortuous and close to the superior mesenteric artery contained an aneurysm measuring 6 mm × 10 mm. No extravasation of contrast medium. The aneurysm corresponded to the position of the duodenal stenosis. Operation: The hematoma noted at operation two months previously had disappeared and the proximal part of the superior mesenteric artery was embedded in firm connective tissue. The aneurysm lay between the duodenum and the pancreas; no actual bleeding. Resection was performed. The patient is now free of symptoms.

This case should be compared with Case 5 in OLSSON (1971) and Cases 2, 4 and 5 in part I.

Discussion

Various roentgen changes in the duodenum make the differential diagnosis difficult and a definite diagnosis impossible. This holds for ulceration of unusual

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ANGIOGRAPHY OF THE PANCREAS FOLLOWING THE ADMINISTRATION OF SECRETRIN, TRYPSIN AND HISTAMINE

by

RUDOLF SCHMARSOW

Much experimental work has been carried out in recent years to obtain roentgen demonstration of detail of the pancreas. Investigations in animals have revealed that halogenated zinc compounds (SHAPIRO 1957) and acridine compounds (MOSELEY 1961) were concentrated selectively in this organ. Unfortunately, however, these substances are too toxic and insufficiently stable for use in man. KISSLER et coll. (1964) employed secretin before the intravenous injection of the contrast medium. This combined with retroperitoneal pneumography produced reasonable representation of the pancreas. BENNET et coll. (1967) and ROSENBUSCH et coll. (1969) used the intra-arterial administration of secretin successfully in some cases. UDEN (1969) employed pancreatic angiography and administered cholecystokinin pancreozymin alone or combined with secretin and gastric insufflation in 20 patients to produce an increase in the blood flow through the pancreas as well as in the width and contrast filling of

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ZUSAMMENFASSUNG

Vollständig unterschiedliche Typen von Erkrankungen können Duodenalveränderungen hervorrufen, die bei konventionellen Barium-Untersuchungen nicht voneinander unterschieden werden können. Die Bedeutung der Angiographie in der Differentialdiagnose wird im Hinblick auf sieben ausgewählte Fälle besprochen.

RÉSUMÉ

Des types de lésions du duodénum complètement différentes peuvent donner, par l'examen baryté habituel, des signes absolument indiscernables les uns des autres. L'auteur étudie, en se basant sur 7 cas choisis, le rôle de l'angiographie dans les moyens de diagnostic.

REFERENCES

BOIJSEN E. and SAMUELSSON L.: Angiographic diagnosis of tumours arising from the pancreatic islets. Acta radiol. Diagnosis 10 (1970), 161.

BOSSE G. and NEELY J.: Roentgenologic findings in primary malignant tumors of the duodenum. A report of 27 cases. Amer. J. Roentgenol. 107 (1969), 111.

BRUWER A. and HALLENBECK G.: Aneurysm of hepatic artery: roentgenologic features in one case. Amer. J. Roentgenol. 78 (1957), 270.

GUIDA P. and MOORE S.: Aneurysm of the hepatic artery. Report of five cases with a brief review of the previously reported cases. Surgery 60 (1966), 299.

LUNDERQUIST A.: Angiography in carcinoma of the pancreas. Acta radiol. (1965) Suppl. No. 235.

— LUNDERQUIST A. and KNUTSON H.: Angiography in Crohn's disease of the small bowel and colon. Amer. J. Roentgenol. 101 (1967), 338.

McLEAN ALVARADO G., VILLARREAL H., BRODERS A. et coll.: Aneurysm of the hepatic artery. Amer. J. dig. Dis. 12 (1967), 509.

NELSON S.: Some interesting and unusual manifestations of Crohn's disease ("regional enteritis") of the stomach, duodenum and small intestine. Amer. J. Roentgenol. 107 (1969), 86.

OLSSON O.: Angiographie bei Pankreastumoren. Radiologe 5 (1965), 281.

— Angiography in tumors of the pancreas. In: Progress in radiology, p. 420. ICS No. 105. Excerpta Medica Foundation, Amsterdam 1965.

— Angiography in duodenal cancer. In: Proceedings of the Scandinavian Society of Medical Radiology Congress, p. 107 (abstract). Copenhagen 1968.

— Angiography in tumours of the pancreas. In: Modern trends in diagnostic radiology. Edited by J. W. McLaren. Butterworths, London 1970.

— Angiography in duodenal carcinoma. Acta radiol. Diagnosis 11 (1971), 177.

— Angiography in the diagnosis of duodenal lesions. I. Differentiation between primary duodenal carcinoma and carcinoma of the head of the pancreas involving the duodenum. Acta radiol. Diagnosis 12 (1972), 19.

SALIK J.: Pancreatic carcinoma and its early roentgenologic recognition. Amer. J. Roentgenol. 86 (1961), 1.

SWEETMAN W. and WEINSTEIN M.: Hepatic and celiac artery aneurysms. J. Amer. med. Ass. 197 (1966), 153.

ZBORALSKE F. and AMBERG J.: Detection of the Zollinger-Ellison syndrome: the radiologist's responsibility. Amer. J. Roentgenol. 104 (1968), 529.

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by

RUDOLF SCHMARSOW

Much experimental work has been carried out in recent years to obtain roentgen demonstration of detail of the pancreas Investigations in animals have revealed that halogenated zinc compounds (SHAPIRO 1957) and acridine compounds (MOSELEY 1961) were concentrated selectively in this organ Unfortunately however the e substances are too toxic and insufficiently stable for use in man KISSLER et coll (1964) employed secretin before the intravenous injection of the contrast medium This combined with retroperitoneal pneumography produced rea onable repre entation of the pancreas. BENNET et coll (1967) and ROSENBUSCH et coll (1969) used the intra arterial administration of secretin successfully in some ca es UDEN (1969) employed pancreatic angiography and administered cholecystokinin pancreozymin alone or combined with secretin and gastric insufflation in 20 patients to produce an increase in the blood flow through the pancreas as well as in the width and contrast filling of

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the pancreatic vessels, this proved useful in the diagnosis of pancreatic carcinoma and cysts. This author sometimes obtained a *pancreatographic effect*. The technique was based on the fact that secretin increases the blood flow to the pancreas as demonstrated in animal experiments by MAITESOS & WATSON (1939). UDEN mentioned that the secretin induced increase in the blood flow is associated with greater oxygen consumption by the pancreas. One clinical unit of secretin/kg body weight administered intravenously increases the oxygen uptake in the pancreas four or five times within three minutes. Tomography (frontal, sagittal, transverse axial) after retroperitoneal insufflation and eventually gastric insufflation was used by VALLEBONA (1967). This method has provided a direct roentgenologic representation of the normal pancreas as well as of its enlargement and the changes in its neighbouring regions.

RICH & DUFF (1936) performed experimental investigations with activated trypsin and observed changes in the blood vessels of the pancreas. STEIN et coll. (1956) by injecting drawing ink and trypsin in a pancreatic artery in dogs demonstrated staining of the stroma of the gland; this indicated that the walls of the capillaries are made permeable by this drug. They recorded that high doses produced pancreatitis but the intravenous infusion of 5 mg to 15 mg of trypsin in rabbits failed to cause any side effects. The important property of trypsin injected intra-arterially is that the walls of the capillaries are made permeable and this favours the penetration of the contrast medium into the stroma of the pancreas and contributes to the pancreatographic effect. McCUNE & STANBRO (1959) made use of this effect by injecting trypsin intra-aortically followed by Hypaque 90 % and reported some demonstration of the pancreas in 70 % of dogs. They combated the histamine-like action of trypsin with pyribenzamine. Histology of the pancreas revealed no evidence of pancreatitis. INNERFIELD (1952) used intravenous trypsin in thrombophlebitis and observed a thrombolytic effect with prolongation of the bleeding and coagulation times. A useful conclusion of the last mentioned author was that this substance slowly and cautiously administered, even in large doses (100 mg/kg), fails to produce shock. IACNON (1944 and 1945) injected up to 325 mg in twenty minutes in hemophilic patients and observed significant shortening of the *coagulation time* for one hour. This author stated that extreme caution in the intravenous administration of trypsin avoided any danger.

Technique. Selective angiography of the celiac axis and superior mesenteric artery was performed simultaneously by the percutaneous transfemoral catheter method on both sides so as to obtain complete cover of the pancreas. Demerol (a preparation of meperidine) 25 mg, fenergan (an antihistaminic) and atropine sulfate 0.5 mg had previously been administered; one examination was performed without pancreas circulation stimulating drugs. A film in the arterial phase



Fig 1 Case 1 Carcinoma of the gallbladder with liver metastases and micronodules in the pancreas Tumour vessels in inferior parts of l er Splenomegaly Angiography without secretin trypsin or histamine

and one in the venous phase were obtained by manual manipulation becau e of the absence of an automatic film changer excepting in the last case in which a changer was used About 70 ml Hypaque 50 % were injected with a Gidlund injector An amount of 75 U secretin was injected intravenously in 19 patients and intra arterially in 4 patients This was followed after 15 minutes by 25 mg of stabilised crystalline trypsin (Novo) dissolved in 100 ml physiologic saline and then by 0 5 mg histamine intra arterially through the catheters The last drug was added to reinforce the histamine like effect of trypsin and to dilate the pancreatic arteries ba ed on the premi e that histamine dilates all splanchnic arteries (SOLLMAN 1935) A film in the arterial phase and one in the venous phase were then obtained finally a prophylactic antihistaminic was injected

The method described was employed in 23 patients 20 males and 3 females ranging in age from 22 to 60 years with various conditions of the liver, gas trointestinal tract and pancreas

Case reports

Case 1 (Figs 1 2) Male aged 22 with carcinoma of the gallbladder and hepatic m tastases indicated by tumour vessels Blood bilirubin elevat d (16 5 mg %) Following injection of the three drugs and insufflation of the stomach angiography revealed down ward displacement of the body and tail of the pancreas by an enlarged spleen the latter



Fig. 2. a) Same case as in fig. 1 with gastric insufflation and secretin, trypsin and histamine. Normal outline of pancreas but body and tail displaced downwards. Some of the contrast medium lies in the duodenum. b) Subtraction.

was probably caused by portal hypertension due to malignant infiltration. The apparent enlargement of the head of the pancreas (Fig. 2 b) was actually caused by superposition of part of the duodenum. Autopsy disclosed a pancreas of normal size with metastatic micronodules.

Case 2 (Fig. 3). Female aged 52, with obstructive jaundice (bilirubin in blood 20.75 mg %). Angiography after the injection of the three drugs without insufflation of the stomach yielded a good pancreatographic effect. The whole pancreas was somewhat enlarged with homogeneous impregnation of contrast medium. No clinical evidence of pancreatitis. The pancreas was even better represented with the subtraction technique.



a



b

Fig 3 (a) Case 2 Obstructive jaundice Angiography without the three drugs (b) Angiography with secretin trypsin and histamine Pancreas well filled but somewhat enlarged

Case 3 (Figs 4 5) Male aged 46 with pancreatitis due to chronic alcoholism (bilirubin in blood 1 75 mg %) Angiography after the injection of the three drugs and insufflation of the stomach revealed mottling of the pancreas due to chronic pancreatitis Similar appearances were reported by LECHNER & POKIESER (1971) in a patient with pancreatitis suggesting that these may be characteristic of chronic inflammation



Fig 1 Case 3 Chronic alcoholic pancreatitis Angiography without the three drugs

Results

The pancreas was demonstrated in 17 out of 23 patients In 2 patients the pancreas was somewhat enlarged and in one patient a mottled appearance probably due to chronic pancreatitis was present In 5 patients it was possible to depict only the body and tail of the pancreas and in 1 only the head although in 11 patients the whole organ was outlined The pancreas was usually visible in the arterial as well as in the venous phase

The dose per kg body weight ranged from 1 9 U/kg to 1 U/kg, for secretin, from 0 0125 mg/kg to 0 007 mg/kg for histamine and from 0 63 mg/kg to 0 35 mg/kg for trypsin An elevation in the dose of secretin failed to produce any improvement in several patients examined before the present series

The amylase or glucose, or both, in the blood after the examination was normal in 17 patients excepting in 1 patient in whom a slight elevation of the amylase was detected (232 Somogyi units) One patient with moderate hepatic cirrhosis had hematemesis and melena probably due to trypsin but easily controlled 5 hours after the examination No alteration in the blood pressure could be detected after injection of the three drugs

The pancreas could not be identified in 6 patients but in one of these it was possible to inject only a tenth of the required amount of trypsin (2 5 mg) because of acute epigastric pain Another patient had a large cyst of the head and body of the pancreas, the tail being partially extirpated (Duval method) so that a small part only of the organ was left No explanation of the inability to outline the pancreas in 4 patients was forthcoming, probably due to a failure



a



b

Fig 5) Same case a. in fig 4 Angiography with secretin trypsin and histam ne Mottling of pancreas due to chronic pancreatitis b) S btraction

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Comments

Different combinations of two of the stimulating drugs (secretin trypsin and histamine) had been tried without satisfactory repre entation of the pancreas before the pre ent series of examinations The drug combination that

became the standard in the present investigation seemed to be the best one and apparently the intravenous injection of secretin yields better results than the intra-arterial administration. As mentioned no improved result could be obtained by a higher dose of secretin. An increase in the dose of trypsin or a higher concentration in some of the patients of the previous material produced acute epigastric pain. A raised dose of histamine also failed to improve the results.

The failure of the pancreas to contain any contrast medium seems to be of little significance because the 4 patients mentioned had no clinical or laboratory evidence of disease of the pancreas. It is interesting that the best representation of the pancreas was achieved in 2 patients with considerably elevated blood bilirubin. It is possible that bilirubin has a permeabilizing effect on the capillaries, perhaps similar to that of trypsin or that it produces a prolongation of the trypsin activity in the blood.

The method described may possibly provide the differential diagnosis between chronic pancreatitis and carcinoma. A mottled impregnation of the whole pancreas will favour a diagnosis of chronic pancreatitis.

Acknowledgement

The author is indebted to Novo Industri A/S for providing the trypsin. The secretin was obtained from CIH Research Unit, Kemiska Institutionen, Karolinska Institutet.

SUMMARY

An angiographic method of outlining the pancreas by the previous injection of secretin, trypsin and histamine was investigated in 23 adult patients with diseases of the liver, gastrointestinal tract and pancreas. Demonstration of the pancreas was obtained in 17 patients with good outlining of detail in 5 patients.

ZUSAMMENFASSUNG

An 23 Erwachsenen, die an einer Leber-, Pankreas- oder Magendarmerkrankung litten, wurde eine Angiographie nach vorheriger Gabe von Sekretin, Trypsin und Histamin vorgenommen. In 17 Fällen konnte das Pankreas sichtbar gemacht werden, in 5 Fällen erlaubte die Methode eine wirklich gute Darstellung.

RÉSUMÉ

L'auteur a essayé sur 23 adultes atteints d'affections hépatiques, gastro-intestinales et pancréatiques une méthode angiographique qui met en évidence le pancréas après injection préalable de sécrétine, de trypsine at d'histamine. Il a obtenu la mise en évidence du pancréas dans 17 cas, avec des images bien détaillées dans 5 cas.

REFERENCES

BENNET J CHERIGIE E CAROLI J et coll La pancréatographie apres stimulation par la sécrétine intra artérielle À propos de 33 cas Ann Radiol (Paris) 10 (1967) 617

INNERFIELD I SCHWARTZ A W and ANGRIST A A Fibrinolytic and anticoagulant effects of intra venous crystalline trypsin Bull N Y Acad Med 28 (1952) 537

KISSELER B LEISTNER G H and BARTH E A new method for the roentgenologic opacification of the pancreas Radiology 83 (1964) 6

LECHNER G und POKIESER H Ergebnisse angiographischer Untersuchungen bei Pankreatitis Fortschr Rontgenstr 114 (1971) 49

MALTESOS C und WATSON R H Durchblutung und Sekretion des Pancreas bei humoraler Anregung Pflugers Arch ges Physiol 241 (1939) 516

McCUNE W S and STANBRO W W Visualization of the pancreas by aortography Ann Surg 150 (1959) 561

MOSELY JR R D Roentgendiagnosis of pancreatic disease Arch intern Med 107 (1961) 31

MOSKOWITZ H CHAIT A and MELLINS H Tumor encasement of the celiac axis due to chronic pancreatitis Amer J Roentgenol 104 (1968) 641

RICH A R and DUFF G L Experimental and pathological studies on pathogenesis of acute hemorrhagic pancreatitis Bull Johns Hopk Hosp 58 (1936) 212

ROSENBUCH G und CEN M Zoliakographie mit Sekretin Moglichkeiten der Pharmakoangiographie in der Pankreasdiagnostik Fortschr Rontgenstr 110 (1969) 639

SHAPIRO R Experimental opacification of the pancreas A preliminary report Radiology 69 (1967) 690

SOLLMAN T Farmacologia y sus aplicaciones a la terapeutica y a la toxicologia (In Spanish) Editores Salvat S A Barcelona 1955

STEIN A A POWERS S R and BROWNE H H Experimental hemorrhagic pancreatitis New concepts of pathogenesis Ann Surg 143 (1956) 508

TAGNON H J Effect of intravenous injection of trypsin on the blood coagulation time in hemophilia Proc Soc Biol (N Y) 57 (1944) 45

— The nature of the mechanism of the shock produced by the injection of trypsin and thrombin J clin Invest 24 (1945) 1

UDEN R Effect of secretin in celiac and superior mesenteric angiography Acta radiol. Diagnosis 8 (1969) 497

VALLEBONA A Tomography of abdominal organs *In* Progress in radiology Vol I p 235 Edited by L Turano A. Ratti and C Biagini ICS No 105 Excerpta Medica Foundation Amsterdam 1967

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Fig 1 Right renal stasis 2 hours after 40 ml Isopaque 350 Average gallbladder filling

Fig 2 Right renal stasis 6 hours after 250 ml Isopaque infusion Gallbladder well filled

Fig 3 Left renal stasis 6 hours after 250 ml Isopaque infusion Average gallbladder filling

than one uremic patient SHEA & PFISTER (1959) (4 cases), ARKLESS (1969) (one case) OLSSON (1971) was the only author reporting filling of the gallbladder with metrizoate (Isopaque, (several cases) A material of 26 cases of gallbladder filling after metrizoate urography and 4 cases in which sodium diatrizoate was the contrast medium are now presented

Group I This consisted of 5 cases in which during a period of six months filling of the gallbladder occurred within 1 to 4 1/2 hours of the injection of 40 ml Isopaque 350 in a large total number of urographies These were emergency cases examined mostly at night Four of the cases were of renal stasis with calculi the stone had been passed in the fifth case two days before the actual urography (Fig 1)

Group II An extra film was obtained at six hours in a consecutive series of 127 urographies over a three month period The Isopaque (250 ml at 150 mg I/ml) was perfused in 5 to 7 min Filling of the gallbladder was demonstrable in these films in 21 cases it was marked in one case (Fig 2) average in 6 (Fig 3) and poor in the other 14 cases (Fig 4)

Group III The significance of the nature of the contrast medium was investigated in a series of 96 urographies with sodium diatrizoate (250 ml Urografin 30 %) Poor filling of the gallbladder resulted in 4 cases at six hours (Fig 5) The 21 Isopaque cases in group II included 6 with stasis and 2 that had had stasis less than two days before the urography the other cases were normal The findings in all the 4 Urografin cases of group III were also normal

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GALLBLADDER FILLING BY UROGRAPHIC SODIUM METRIZOATE

by

R. KOHLER and J. EDGREN

Heterotopic excretion of urologic contrast media is regarded as rare. The injection of a wrong preparation was even considered in a similar connection (ARENDT & ZGODA 1957) or control of the medium injected was thought to be indicated (PREUSS 1970). Sodium acetrizoate (Urokon) is an exception, however. According to ORLOFF (1955), the gallbladder was filled in 26 of 28 cases four to eight hours after the administration of 50 ml Urokon and, according to WOOLLEY et coll. (1957), in 12 out of 25 cases two hours after the injection of standard doses of Urokon 70 %.

Few case reports on filling of the gallbladder when sodium iodomethamate (Uroselektan B) or iodopyracet (Perabrodil) was used (collected by SCHERMULY 1958) appeared before 1955. Despite the sharply rising investigation figures, few reports on gallbladder filling with modern contrast media for intravascular injection have been published. The first isolated cases in which a diatrizoate preparation (Hypaque, Urografin, Renografin) was employed were published at the end of the 1950s (ARENDT & ZGODA, SCHERMULY). The greatest number of cases reported by a single author is five (SEGALL 1969). Iothalamate (Conray) has also been found to cause heterotopic gallbladder filling. SEGALL more

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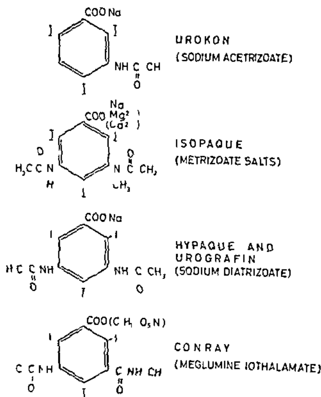


Fig. f Structural formulae

when intravenously administered is thus excreted via the liver in normal human subjects (PORPORIS et coll 1954). This accounts for the previously mentioned normal filling of the gallbladder in urography with Urokon (ORLOFF, WOOLLEY et coll.)

Isopaque (a balanced mixture of sodium, calcium, magnesium and N-methyl glucamine salts of metrizoate acid), Hypaque and Urografin (sodium diatrizoate) and Conray (meglumine iothalamate) are closely related to one another and have a completely substituted benzene ring. In conformity with this and according to the literature sodium diatrizoate displays little affinity for the gallbladder when the renal function is normal. HANSSON & LINDHOLM (1963) inter alios have reported that Hypaque injected intravenously into rabbits with normal renal function is eliminated in more than 99 per cent of animals through the kidneys. DENNEBERG (1965) demonstrated biliary excretion



Fig. 4. Right hydronephrosis 6 hours after 250 ml Isopaque infusion. Poor filling of gall bladder



Fig. 5. Six hours after 250 ml Urografin 30 % infusion. Poor filling of gallbladder

Only minor deviations were established when the laboratory data in all 30 cases of the three groups were combined. The specific gravity, pH, total serum protein, serum calcium and phosphorus of the urine were within the normal range in all the cases. Two cases in group I had a slightly elevated serum creatinine value (1.5 and 1.9 mg/100 ml). A value of 1.8 was recorded for a case without stasis in group II and of 1.5 in one with stasis in the same group. The other cases yielded normal values as did all those in group III.

Discussion

Contrast media for intravascular injection are excreted mainly via the kidneys or liver and to a small extent through the small intestine. The chemical structure of the iodine contrast media, and accordingly the binding to plasma protein, were regarded by Lasser et coll. (1962) as decisive in determining the route of elimination. The more highly protein bound preparations appeared to be preferentially excreted in the bile and the less highly bound in the urine. The structure of the benzene ring probably controls the route of elimination. If position 5 in this ring is unsubstituted the binding of the medium to albumin is favoured and affinity for the liver is likely. The binding to albumin is weak and the excretion mainly urinary should the ring be completely substituted.

The structural formulae (Fig. 6) of the four preparations reveal that position 5 is unsubstituted in Urokon: approximately 20 per cent of this contrast medium

HANSSON & LINDHOLM in experiments on the severest possible renal impairment i e where animals were nephrectomized observed in the first 24 hours excretion of no less than a quarter of the injected dose of Hypaque via the liver and the passage of a seventh into the intestine along other paths BECKER et coll injected sodium diatrizoate into anephric dogs and observed vicarious excretion to the gut as well as the liver with filling of the gallbladder ARENDT & ZGODA advanced the hypothesis that neurovascular reflexes between the kidney and liver and gallbladder clinically constitute the background of filling of the latter An increased number of circulatory passages through the liver with a magnification of the hepatic extraction was suggested by SHEA & PFISTER as the cause These authors considered that the situation may be the same in unilateral ureteric obstruction BECKER et coll suggested that the protein binding of sodium diatrizoate could be increased in cases of uremia It was established by DAWSON et coll and STOKES & TER POGOSSIAN (1964) that a metrizoate differed from a diatrizoate contrast medium as regards its disappearance from the blood in that its half life in the first of the two-rate processes was considerably shorter i e 15 min compared with 52 min

OLSSON supported by this statement advanced the hypothesis that this difference would explain the excretion of a metrizoate substance *through the liver* and faster filling of the gallbladder when acute unbalanced renal stasis was present This explanation appears to be plausible in relation *to the greater* likelihood of a metrizoate contrast medium being excreted via the *liver in renal* stasis it will however not account for the occasional failure of the gallbladder to fill in normal urographies The information available suggests that a *raised* tendency to heterotopic liver excretion of urographic contrast media *exists in* pathologic renal conditions

The administration of large quantities of a contrast medium should increase the possibility of liver uptake and consequently filling of the gallbladder *This* is probably an important reason for the frequent *demonstration* of filling of the gallbladder in the present material Delayed *filming naturally* also increased the possibility of gallbladder filling as this usually occurs *only some hours* after the injection of the contrast medium the reason for this is that the excretion rate per time unit is *small*

Factors (1) to (4) represent circumstances that favour *heterotopic* excretion of contrast media it is however not possible from these to offer an exhaustive explanation of this phenomenon for exceptions have been encountered RETHELYI for example, *reported gallbladder filling* in the presence of healthy kidney and most of the *present cases* in groups II and III also had normal kidneys Renal pathology is *thus not essential* for these exceptional phenomena nor are large quantities of contrast medium *necessary* The dose was usually

of only 0.13 and 0.22 per cent of an injected dose of radioactive Hypaque after 24 hours in two human subjects with normal renal function.

Animal experiments have indicated that the elimination factors with the metrizoate and diatrizoate preparations are the same. DAWSON et coll. (1968) reported that six hours after an intravenous dose of 100 mg/kg sodium metrizoate in rabbits or cats the mean recovery from the urine was 88.4 and 86.6 per cent, and from the bile 2.2 and 4.8 per cent, respectively. A total of 86 per cent of the compound was eliminated in the urine in six hours in man.

Experience obtained in the present material fails to fall in line with the simple system of LASSER et coll., nor is there any confirmation of animal experiments nor complete agreement with earlier clinical or radiologic findings. Excretion of contrast medium via the liver is obviously influenced not only by the protein binding ability of the preparation but also by other factors, of which the following may be mentioned:

(1) Severe renal impairment: SCHERMULY: three cases out of six, BECKER et coll. (1968): two cases, SEGALL (1969): two cases out of five, SHEA & PFISTER: one case out of five, OLSSON: one case. Not all publications, however, present clear data which makes their evaluation in this connection difficult. CHAMBERLAIN & SHERWOOD (1966) in three azotemic cases reported 7 to 20 per cent fecal recovery of the contrast medium in a 48 hour stool collection.

(2) Unilateral renal damage or unilateral ureteric obstruction but normal renal function: SCHERMULY: one case with biliary colic, BECKER et coll.: one eight year old child with a large necrotic clear cell carcinoma and the opposite kidney and renal function normal, SEGALL: one case with unilateral biliary colic, RAPOPORT (1969): three cases with high grade ureteric obstruction, SHEA & PFISTER: four cases with unilateral ureteric obstruction, OLSSON: several cases but no data. The 5 cases in group I belong to the above list in that 2 of them had a slightly elevated creatinine level.

(3) The present day administration of large quantities of renal contrast media: BECKER et coll.: two cases with 150 ml Hypaque 90 or Renografin 60 (infusion), SEGALL: five cases with 60 to 200 ml Hypaque or Renografin, SHEA & PFISTER: five cases with 40 to 125 ml Conray 400 or Renografin 60. All the cases in groups II and III had received 250 ml infusion of Isopaque or Urografin.

(4) The late film to demonstrate gallbladder filling. Most cases reported by the authors mentioned had filling of the gallbladder at 24 hours. The cases of obstruction in group I needed 1 to 4 hours for clear demonstration of the gallbladder. No filling of the gallbladder occurred within the normal examination time in groups II and III, that is about 20 min, although it was evident at 6 hours in 25 cases.

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The administration of large quantities of a contrast medium should increase the possibility of liver uptake and consequently filling of the gallbladder This is probably an important reason for the frequent demonstration of filling of the gallbladder in the present material Delayed filming naturally also increased the possibility of gallbladder filling as this usually occurs only some hours after the injection of the contrast medium the reason for this is that the excretion rate per time unit is small

Factors (1) to (4) represent circumstances that favour heterotopic excretion of contrast media it is however not possible from these to offer an exhaustive explanation of this phenomenon for exceptions have been encountered RETHELEY for example reported gallbladder filling in the presence of healthy kidney and most of the present cases in groups II and III also had normal kidneys Renal pathology is thus not essential for these exceptional phenomena, nor are large quantities of contrast medium necessary The dose was usually

20 ml in RETHEFI's collection of Urografin cases from the 1950's. The cases in group I were not given more than 40 ml Isopaque 350. Even a late examination is not always necessary to reveal filling of the gallbladder. RETHEFI reported two unique cases with filling of the gallbladder as early as two and five minutes, respectively. COCKERILL & KURLANDER (1968) and OLSSON described one case each in which the gallbladder was filled within 20 min, SEGALL one case of filling within 30 min, PREUSS one case in which filling occurred within 35 min, SCHERMULY filling at 50 min, ARENDT & ZGODA filling at one hour. Filling of the gallbladder was observed at one hour in one of the present cases.

Both FISCHER and KNOEFEL in 1965 suggested that the significance of the protein binding mechanism in biliary secretion might be only secondary in that it precludes the more rapid loss of the compounds through the glomerular filter. ROSATI & SCHANTARELLI (1970) were able to confirm this premise with their experiments in dogs. They pointed out at the same time the importance of the concentration reached by the substance in the biologic phase involved. This concentration is again determined by the dose, the distribution volume in the body, and the amount of substance lost through the kidneys.

Heterotopic excretion of contrast media for intravascular injection is clearly a complex phenomenon, the reason for which it is difficult to establish with certainty in each individual case. This concerns all modern tri-iodinised contrast media, and not least the metrizoate range, the high frequency of gallbladder filling was established but could not be fully explained. Because of its late manifestation, gallbladder filling usually fails to interfere with urography. The question is of theoretical interest, however, but should inspire further investigation.

SUMMARY

The filling of the gallbladder at urography is discussed. This occurred in 26 of 127 cases (16 per cent) examined with a metrizoate contrast medium (Isopaque) infusion but in only 4 per cent of those receiving sodium diatrizoate (Urografin). Renal or ureteric impairment, the use of large doses of contrast medium and a late film favour demonstration of the gallbladder.

ZUSAMMENFASSUNG

Füllung der Gallenblase bei der Urographie wird besprochen. Diese erfolgte in 26 von 127 Fällen (16 Prozent), die mit Infusion mit Metrizoat-Kontrastmittel (Isopaque) untersucht wurden, jedoch nur in 4 Prozent bei den Fällen, die mit Natrium-Diatrizoat (Urografin) untersucht wurden. Veränderungen der Nieren oder Ureteren, die Verwendung grosser Dosen des Kontrastmittels und eine spätere Aufnahme begünstigen die Darstellung der Gallenblase.

RÉSUMÉ

Les auteurs étudient l opacification de la vésicule biliaire au cours de l urographie Ell s est produite dans 26 cas sur 127 (16 pour cent) examines avec un moyen de contraste au metrizoate (Isopaque) en perfusion mais seulement dans 4 pour cent des cas avec le diatrizoate de sodium (Urografin) Le mauvais fonctionnement du rein ou de l uretere l emploi de fortes doses de moyen de contraste et la prise d un film tardif favorisent la mise en évidence de la vesicule biliaire

REFERENCES

ARENDT J and ZGODA A Heterotopic excretion of intravenously injected contrast media Radiology 68 (1957) 238

ARKLESS R Gallbladder seen on excretory urography a case report J Urol 102 (1969) 765

BECKER J A GREGOIRE A BERDON W and SCHWARTZ D Vicarious excretion of urographic media Radiology 90 (1968) 243

CHAMBERLAIN M J and SHERWOOD T Extrarenal excretion of diatrizoate in renal failure Brit J Radiol 39 (1966) 765

COCKERILL E M and KURLANDER G J Extrarenal excretion of urographic contrast medium in renal failure report of a case of gallbladder opacification simulating renal cyst J Urol 100 (1968) 6

DAWSON J B McCHESSNEY E W and TELLER G F Excretion of metrizoate in man Acta radiol Diagnosis 7 (1968) 50?

DENNEBERG T Clinical studies on kidney function with radioactive sodium diatrizoate (hypaque) Acta med scand (1965) Suppl No 442

FISCHER H W The excretion of iodipamide—relation of bile and urine outputs to dose Radiology 84 (1965) 483

HANSSON R and LINDHOLM T Elimination of hypaque (sodium—3 5-diacetoamido—2 4 6—triiodobenzoate) and the effect of haemodialysis in anuria A clinical study and an experimental investigation on rabbits Acta med scand 174 (1963) 611

KNOEFEL P K Radiopaque diagnostic agents Ann Rev Pharmacol 5 (1965) 321

LASSER F C FARR R S FUJIMAGARI T and TRIPP W N The significance of protein binding of contrast media in roentgen diagnosis Amer J Roentgenol 87 (1962) 338

OLSSON O Excretion of sodium metrizoate through the liver during urography Acta radiol Diagnosis 11 (1971) 85

ORLOFF T L Intravenous cholecystography with new medium experience with sodium acetrizoate (urokon sodium) 70 percent Arch Surg 71 (1955) 620

PORPORIS A A ELLIOTT G V FISCHER G L and MUELLER C B Mechanism of urokon excret on Amer J Roentgenol 72 (1954) 935

PREUSS H J Heterotope Diatrizoat Ausscheidung uber die Leber beim Nierengesunden Fort chr Röntgenstr 113 (1970) 376

RAPOPORT K D Gallbladder opacification after pyelography Letters to the editor Invest Radiol 4 (1969) 398

RETHELY J Über die heterotope Ausscheidung des Urografins Fortschr Röntgenstr 97 (196?) 316

ROSATI G and SCHIANTARELLI P Biliary excretion of contrast media Invest Radiol 5 (1970) 232

SCHERMULY, J.: Die heterotope Ausscheidung von Nierenkontrastmitteln. Fortschr. Rontgenstr. 89 (1958), 220.
SEGALL, H. D.: Gallbladder visualization following the injection of diatrizoate. Amer. J. Roentgenol. 107 (1969), 21.
SHEA, T. F. and PFISTER, R. C.: Opacification of the gallbladder by urographic contrast media. Amer. J. Roentgenol. 107 (1969), 763.
STOKES, J. M. and TER-POGOSSIAN, M. M.: Double isotope technique to measure renal functions. J. Amer. med. Ass. 187 (1964), 20.
WOOLLEY, I. M., KEIZUR, L. W. and MAYER-HARNISCH, G.: Gallbladder visualization following the use of 70 per cent sodium acetrizoate (urokon sodium) for intravenous pyelography. Radiology 69 (1957), 576.

FROM THE KLINIKA RADIOLOGICZNA AND THE III KLINIKA CHIRURGICZNA AKADEMII MEDYCZNEJ, WROCLAW POLAND

THE RADIOLOGIC APPEARANCE OF THE RECONSTRUCTED ESOPHAGUS

by

FRANCISZEK K. TUSZEWSKI

The present investigation consists of an evaluation of the radiologic appearances and function of the surgically reconstructed esophagus by means of transplanted segments of colon and ileum or jejunum. Cicatricial stenosis of the esophagus is a common lesion in clinical practice and most often results from the swallowing of corrosives such as caustic soda or hydrochloric acid. Stenosis may also occasionally follow bouts of diphtheria, scarlet fever or prolonged reflux esophagitis. Exceptionally it may also result from mechanical trauma.

The most common method of treating esophageal stenosis is dilatation by means of bougies. Preliminary good results may often be obtained but are not always permanent. Complications, particularly perforations, are not uncommon. Treatment by means of a feeding gastrostomy on the other hand does not resolve the problems attendant upon a patient who is unable to swallow his own saliva. It also burdens him with a major cosmetic disability. Surgical efforts have consequently been made to connect the oral cavity and the stomach and to restore the physiologic function of both the esophagus and the cardia.

Attempts at surgical reconstruction of the esophagus date from the second half of the 19th century. Among pioneers BILLROTH, BIRCHER, MIKULICZ and others may be mentioned (ROSSETTI 1963). Initially attempts were made to connect the oral cavity and the stomach by means of a skin tube but during the period 1900—1920 techniques of stomach mobilization and transposition

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into the chest were proposed, methods of mobilization of the large as well as of the small intestine were also suggested. The very first of these attempts aimed at combining the new technique with the older one of skin tubing. The artificial esophagus so constructed was at first implanted subcutaneously. The development of thoracic surgery enabled esophageal replacements to be inserted into the mediastinum, thus achieving both a shortening of the distance to be grafted as well as improving the cosmetic results (1, 4, 16, 23, 28, 29, 31). Attempts were also made at utilizing metallic spirals and pipes (33). Lastly the newer synthetics were also called upon to play a role (3, 20).

Our surgical clinic has been active in this field since 1950. The first esophageal reconstructions were made by the antethoracic subcutaneous route, segments of jejunum being utilized. Next, jejunal grafts were placed in the anterior mediastinum (11, 12, 13). Angiography of the potential intestinal segments indicated that in order to secure adequately vascularized segments of the gut long enough to reach the hypopharynx, the part of the intestine supplied by the ileocolic group of vessels was best (7, 8, 14). Based on these findings JEZIORO developed reconstruction methods that utilized the terminal ileum, the ileocecal valve and the cecum (*ileocecoplasty*), as well as the *right side of the colon* (antiperistaltic coloplasty). Isoperistaltic coloplasty methods introduced by MONTENEGRO were also used in some cases. Ileocecoplasty proved in practice to be a method that ensured good functional results (26), but was technically difficult and at times impossible because of hypoplasia of the main arterial and venous trunks that had to be utilized. Coloplasty on the other hand proved to be technically simpler, but its late functional results left much to be desired (24). Complications were frequent (17, 19).

Both early and late complications may be encountered following these two procedures. The functional results are not invariably good (8, 17, 19, 24, 26, 27, 31). This was the reason why other more elaborate multisegmental reconstruction methods were developed. Segments of the terminal ileum and cecum, or segments of jejunum were interposed at the lower end of the reconstructed esophagus by anastomosing them superiorly to the colonic transplant and inferiorly to the stomach. The JEZIORO variations thus include (9, 10, 15):

(1) Esophageal reconstruction by the use of a part of the colon with interposed segments of terminal ileum, ileocecal valve and cecum (utilizing the ileocolic arterial and venous trunks. This method is termed 'anisoperistaltic coloileocecoplasty' (Fig. 1).

(2) Esophageal reconstruction with a part of the colon supplied by the left colic artery with interposition of a segment consisting of the terminal ileum, ileocecal valve and cecum (supplied by the ileocolic artery). This method is termed 'isoperistaltic coloileocecoplasty' (Fig. 2).

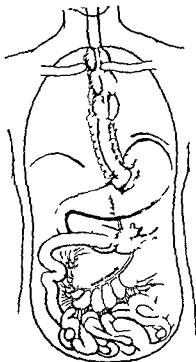


Fig 1 Anisoperi taltic coloileocecoplasty group A 1)

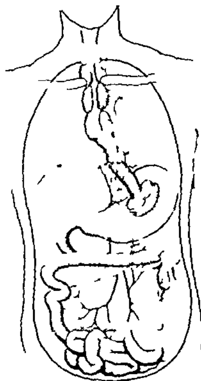


Fig 2 Isoperistaltic coloileocecoplasty (group A 2)

(3) A correctional operation of the anisoperistaltic coloplasty (on the ileocolic arterial and venous trunks) by econdary amputation of the lowermost part of the colonic part of the reconstructed esophagus and its replacement by a segment of the jejunum supplied by the superior me enteric artery and vein anisoperistaltic coloplasty with secondary jejunal interposition (Fig 3)

Radiologic examination The purpo e of the radiologic examination consisted of an evaluation of the functional results (8, 12) assessment of the morphology of the reconstructions and of early as well as of late complications The examination routine and the contrast media used were as follows

Propyliodon (propyl 1 4 dihydro-3, 5 di iodo-4-oxopyridylacetate) (Cilag Chemie Schaffhausen) was mainly used whenever complications were possible e g e ophagomediastinal fistula anastomotic fistula or deficient swallowing reflex with a piration of contrast medium into the bronchial tree This contrast medium has been extensively employed also by other authors (5 8 30)

into the chest were proposed, methods of mobilization of the large as well as of the small intestine were also suggested. The very first of these attempts aimed at combining the new technique with the older one of skin tubing. The artificial esophagus so constructed was at first *implanted subcutaneously*. *The development* of thoracic surgery enabled esophageal replacements to be inserted into the mediastinum, thus achieving both a shortening of the distance to be grafted *as well as improving the cosmetic results* (*1, 4, 16, 23, 28, 29, 31*). Attempts were also made at utilizing metallic spirals and pipes (33). Lastly the newer synthetics were also called upon to play a role (3, 20).

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Table

Materials and methods used in the investigation

Group	Reconstruction method	No. of patients examined	Number and methods of examination					Comments
			By mouth			Gastrostomy	Naso-gastric tube	
			Propyliodon	Barium	With food			
A 1	Anisoperistaltic coloileocecoplasty	11	3	43	1	4	1	
A 2	Isoperistaltic colileocecoplasty	11	1	35	2	5	1	
B	Coloplasty with secondary jejunal interpositioning	8	1	35	5	4		
C 1	Anisoperistaltic coloplasty	33	1	107	3	7	2	—8 to B
C 2	Isoperistaltic coloplasty	11	2	24	2	3		
D	Ileocecoplasty	14		29	1	1		
E	Jejunoplasty	21		38	1			
F 1	Ileocecocoloplasty	2		7	1			
F	Subcutaneous jejunoplasty	3		4				
F 3	Short interposed segments	4		7		1		

Eight patients from group C 1 subsequently reoperated by resection with secondary jejunal interpositioning are now in group B

Material A total of 382 radiologic examinations were performed in 118 cases during the past six years Most cases were examined at least two or three times usually because of early or late complications A small number was examined only once Follow up examinations were carried out a various times following operation The shortest time was 11 days and the longest over 10 years postoperatively The first examination was usually performed at three to five weeks with a second examination three to six months later A third examination followed after a year or two Equipment for cinematography was unfortunately not available but multiple films were exposed at each examination Cinematography would have provided a more objective method for evaluation of peristaltic function (26) The material and methods used are given in the Table

Radiologic classification The transplanted segments of colon and ileum undergo partly a physiologic transformation Without knowledge of the method used at the reconstruction it is usually impossible to determine by radiologic

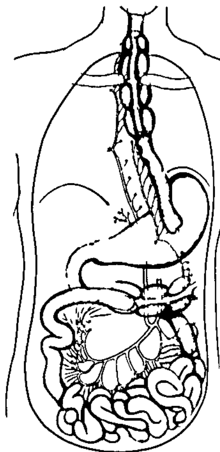


Fig 3 Anisoperistaltic coloplasty with secondary jejunal interpositioning (group B)

Ordinary barium sulfate emulsion of a consistency varying from a thin liquid to a paste was also sometimes used Bread rolls impregnated with barium sulfate were employed where it was desired to imitate as much as possible the normal swallowing (mentioned also by other authors (22, 35) in the investigation of the function of the resected stomach and after gastroenterostomy) Barium sulfate was administered via the gastrostomy before the esophageal reconstruction The most frequent purpose of these examinations was to assess the presence and extent of concomitant cicatricial or corrosive injury to the stomach or duodenum (18, 21) Barium sulfate was also administered via the gastrostomy after the esophageal reconstructions had been completed to reassess the lesions, and evaluate the new cardia by testing for reflux (Fig 15) Barium emulsion via a nasogastric tube was used for detailed examination of the distal reconstructed segments, the examination with the patient supine was possible in only approximately 44 per cent of instances, i e only when the terminal reconstruction segment was empty but the stomach still filled

Anatomy and physiology of the reconstructed esophagus The radiologic appearance of the esophagus reconstructed by one of the following methods will be considered (see Table)

(A 1) retrosternal anisoperistaltic coloileocecoplasty (Figs 1 4),

(A 2) retrosternal isoperistaltic coloileocecoplasty (Figs 2 4) and

(B) anisoperistaltic coloplasty with an interposed jejunal segment (Fig 3)

The anatomy and physiology of each segment and its anastomoses will first be described and then the reconstruction as a whole so as to simplify the radiologic findings in cases of reconstructions composed of two separate segments of the gut

The radiologic appearance of the heart and lungs is unaltered Collections of air may appear in the colonic parts of the esophagus (Fig 5) with smaller *quantities* in the small gut segments The swallowing of saliva or other liquids may then produce fluid levels The amounts of air present in cases examined serially are usually constant although a few variations may appear The amount of air present does not depend on whether the function of the esophagus is adequate or not The excited or nervous patient is likely to exhibit more retained air than the one who is composed

Cervical esophagus The pharyngolaryngeal area and the remnant of the natural cervical esophagus do not as a rule exhibit any changes This is due to the fact that cicatrization due to caustic burns mainly tends to be situated further down at the level of the bifurcation of the trachea or in the distal part of the esophagus Barium sulphate suspension of various consistencies as well as barium impregnated bread rolls pass quickly through this region Stenosis of this segment was evident in a few exceptional cases Serial radiologic examinations as well as questioning of the patients always indicated both a radiologic as well as a subjective relief of the stenosis within a few weeks postoperatively The relative stenosis was apparently due to a transient postoperative edema of the tissue (cf p 200)

Upper anastomosis (anastomosis I) Anastomosis between the cervical remnant of the esophagus and the drawn up colon may be performed either end to end (Fig 6) (end of cervical esophageal remnant anastomosed to end of colon) or side to-end (side of cervical esophageal remnant anastomosed to end of colon) Radiography failed to indicate which method was used in the anastomosis construction in 2 of 33 cases The upper anastomosis is usually made at a level of one to three fingers breadth above the sternal notch No subsequent displacement of the level of this anastomosis up or down has been observed in any of the cases Such a displacement has been reported however by ROSSETTI who considered the cause to be either retraction of the cervical esophageal remnant or



Fig 4 Coloileocecoplasty

means from which segments of the gut and how (iso or anisoperistaltically) it had been built up It is also usually not possible to determine from the radiologic findings on which arteriovenous trunk the reconstruction depends for its blood supply A classification of the radiologic appearance of the reconstructed esophagus must thus be based on surgical principles The author proposes the following groups The esophagus reconstructed by the use of

(A) the colon with an interposed segment of terminal ileum, ileocecal valve and cecum (coloileocecoplasty) (Fig 4),

(B) the colon and an interposed segment of jejunum (colojejunoplasty),

(C) the colon alone (coloplasty) (Fig 14),

(D) the terminal ileum, ileocecal valve and cecum (ileocecoplasty) (Fig 16),

(E) the jejunum only (jejunoplasty), and

(F) other methods

Anatomy and physiology of the reconstructed esophagus The radiologic appearance of the esophagus reconstructed by one of the following methods will be considered (see Table)

(A 1) retrosternal antisoperistaltic coloileocecoplasty (Figs 1 4)
(A 2) retrosternal isoperistaltic coloileocecoplasty (Figs 2 4), and
(B) antiperistaltic coloplasty with an interposed jejunal segment (Fig 3)

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Fig 5 Coloileocecoplasty with air in the reconstruction

the weight of the part of the intestine drawn up into the thorax If the anastomosis is the width of one finger (approximately 1 5 cm), no dysfunction will be evident at radiologic examination and no untoward symptoms will occur

Anastomosis end to end The relatively narrow cervical e ophagus is united with the wider drawn up colon The actual level of the anastomosis is thus recognizable radiologically by the abrupt change in the width of the lumen In addition tiny irregularities are al o sometimes visible at this level where the mucosal folds of the esophagus meet the differently arranged mucosal folds of the colon Barium paste or impregnated bread rolls usually passed quite freely through the anastomosis, and only exceptionally was a delay observed Clinically these patients have complained of distinct difficulty in swallowing but continued observation has revealed that both the symptoms as well as the radiologic signs invariably disappeared within one or two months following surgery It is likely that the changes observed are due to transient postoperative edema of sur rounding structures

Anastomosis side to end This type of anastomosis is best demonstrated in oblique projections as it is usually made at the left anterior lateral aspect of the cervical esophagus Following administration of barium sulfate in such a case a small pouch of the esophagus distal to the anastomosis will be filled while the main part of the contrast medium will pass over to the drawn up intestine The cervical esophagus that had been left in situ had usually not appreciably changed



Fig 6 Coloileocecoplasty anastomosis I (end to end)

at the radiologic examination Atrophy or dilatation had however sometimes developed probably as a result of retained food Detailed discussion of these changes is outside the scope of this communication

Colonic segment of the transplant The colonic constituent of the reconstructed esophagus is situated within the anterior mediastinum in approximately the midline of the body (Fig 7) Anteriorly it is related to the posterior aspect of the sternum and to the heart and great vessels This segment extends from the upper to the middle anastomosis (a little above the diaphragm) The length of the colonic segment is proportional to the length of the chest in adults it is 18 to 25 cm in length most often 23 cm

The upper and lower ends of this segment differ considerably both in structure and function The width of the upper end of the colonic segment measures approximately two fingers breadth The course is straight and smooth with shallow haustrations Slight narrowing of the lumen occurs just below the upper anastomosis due to pressure of the manubrium sterni in approximately half of the cases (Fig 8) During the swallowing of larger bolt of food this area of the reconstructed esophagus moves backwards a mechanism that explains the absence of any symptoms or signs of dysfunction at this level Of particular interest are the mucosal folds of the transplanted colon Just below the level of the upper anastomosis these tend to assume the appearances of elongated

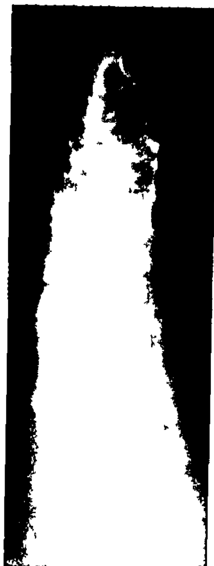


Fig. 7



Fig. 8

Fig. 7. Coloileocecoplasty. Segment of colon containing barium.

Fig. 8. Narrowing of the colonic transplant by pressure of the manubrium sterni.

parallel aligned belts or ribbons that are somewhat thicker than, but otherwise very much like the folds of a normal esophagus (Fig. 9). They occur in the upper part of the transplant about 10 cm distally from the upper anastomosis and after operation gradually become more marked. It must therefore be concluded that they are connected with the adaption of the colonic mucosa to its new function of rapid transport of food. These changes occur within two years after surgery in about 50 per cent of all cases. The term 'esophagisation' of the colonic mucosa is proposed to describe this phenomenon.

The lower part of the colonic transplant segment is approximately three fingers breadth wide, it has definite haustration which is even more marked if



Fig 9 Esophagisation of colonic mucosa

the transplant had been arranged anisoperistaltically The depths of the haustrations are on the whole constant in each case Certain variations may however occur in serial films exposed at 30 minutes 1 hour and 2 hours This indicates active movements of the walls of the colon the passage of contrast medium through the colonic segments is unimpeded At the end of swallowing smears of barium adhere to the walls of the upper part of the colonic transplant while there is puddling of the barium in the lower parts This puddling lasts on an average for 1 hour in anisoperistaltic reconstructions and 2 hours in isoperistaltic reconstructions The conclusion is that the poor emptying observed in cases with colonic transplants have the causative mechanism situated in the lower or most distally situated area This is especially true where the whole of the esophagus has been reconstructed with a single long segment of the colon (cf p 208)

The middle anastomosis (between colon and small gut anastomosis II) This anastomosis unites the relatively large colon transplant with the narrower small gut terminal ileum (Figs 10 11 13) or a part of the jejunum (Fig 12) There are no distinct differences in the radiologic appearances of these two groups The middle anastomosis is situated in the anterior mediastinum at a level approximately two fingers above the diaphragm, close to the midline of the body It is subject to transmitted pulsation from the heart Displacement of the anasto-

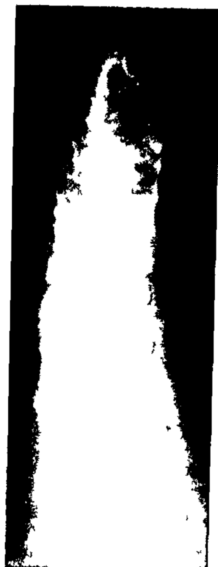


Fig 7





Fig 8

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The lower part of the colonic transplant segment is approximately three fingers breadth wide, it has definite haustration which is even more marked if



Fig 13 Coloileocecoplasty Small bowel segment

The actual location of the anastomosis is recognisable by the changes in the calibre of the lumen and in the mucosal folds The anastomosis was adequate in every case of the series i e no cases with slowing down of the passage or with prestenotic dilatation were encountered The puddling of barium above the middle anastomosis is not related to the width of the opening or the working of the anastomosis but seems to be due to the function of the colonic transplant proper Transient narrowings of this area during the immediate postoperative period were encountered as they had been at the level of the upper anastomosis, these invariably disappeared in time and were therefore presumably due to edema

The segment derived from the small intestine may be built up from the terminal ileum ileocecal valve and cecum (Figs 10 11 13) or from the jejunum (Fig 12) Common characteristics of these two groups are dealt with first

The esophageal reconstruction segment derived from the small gut extends from the middle to the distal anastomosis (anastomosis III) i e down to the junction of the transplant with the stomach The upper part of this segment lies within the anterior mediastinum whilst its longer lower part is situated within the abdominal cavity Its total length depends on the size of the patient on the length of the transplanted colonic segment and on that of the stomach Its length in adult subjects averages 23 cm ($\pm$ 8 cm) The radiologic characteristics of the transplant has not differed in any essential way from those



Fig 10



Fig 11

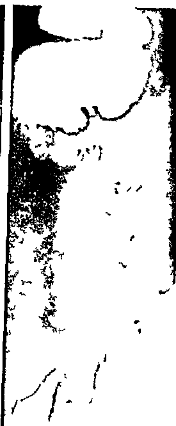


Fig 12

Fig 10 Coloileocecoplasty anastomosis type II (end to end) with segmental interposition of terminal ileum and cecum

Fig 11 Coloileocecoplasty anastomosis II (end to side) with interposition segment of terminal ileum and cecum

Fig 12 Anisoperistaltic coloplasty with secondary jejunal interposition

mosis up or down has not been observed, it moves with the diaphragm during deep breathing

In the JEZIORO operative technique this anastomosis is made either by uniting the end of the transplanted colon to the side of the small gut (Fig 11) or by uniting the end of the colon to that of the small bowel (Figs 10, 13) It was possible in about 60 per cent of the cases to determine at the radiologic examination which method had been used In the remainder this was not feasible by reason of functional transformation of the anastomosis due to technical difficulties which sometimes attended the examination or because of the scarring which was occasionally evident at this level Taking into consideration both the history of the case and the radiologic findings an anastomosis of one finger's breadth (approximately 1 5 cm) seems to be functionally adequate

Distal anastomosis (anastomosis III) This may be either an anastomosis (a) between the cecum and stomach (Figs 11 13), or (b) between the jejunum and stomach (Fig 12) This anastomosis is located on the anterior aspect of the stomach near the lesser curvature About 40 per cent of the ca es had both cicatricial scarring of the e ophagus as well as of the stomach A number of the e underwent initial surgery to restore a gastric lumen and continuity of the gastrointestinal tract The reconstructed esophagus thus had to be anastomosed to such stomach remnants as were still intact usually the middle sometimes the upper parts of the corpus of the stomach (18)

The radiologic appearances of the distal anastomosis have already been dealt with (p 206) The function is evaluated in the appearances of the lumen during passage of swallowed contrast medium and the valve function during the test for gastro-esophageal reflux

No impairment of the speed of the passage of contrast media of varying consistency was noted in any of the anastomotic variations examined This in dicates that the lumina achieved in all of these surgical variants were adequate No gastro-esophageal reflux was demon trated in any ca e with a distal anastomosis of type (a) i e with utilization of the ileocecal valve On the other hand, constant reflux occurred in 2 ca es that had had an anastomosis of type (b) Another case with the latter type of anastomo is had occasional gastro-esophageal *reflux*

The author believes that where the ileo-cecal valve has not been utilized in a po ition to serve as a cardia valve activity is taken over by other mechanisms that include the following (1) Peristaltic stomach directed movements of the jejunum (MULLER BOTHA) (2) compression of anastomosis type (b) and the terminal part of the gut between the anterior abdominal wall and the bulk of the stomach this increa es in intensity with the filling of the stomach (3) the relatively low position of the distal anastomo *is that ensures that* in the head down position of the patient the gastric content flows *into the fornix* and not into the reconstructed esophagus and (4) a hypothetical spasm of the gastric walls urrounding the anastomosis that would *erve to clo e* the lumen It was likely in the 3 cases in which a gastro-esophageal reflux was *pre ent that* mechanisms (2) and (3) were deficient due to residual carring of the gastric walls caused by the original injury by a corro ive In other *words it is likely* that a reflux would have been pre ent in these cases even if the natural e ophagus and cardia had been intact

No changes that could be as ociated with the distal anastomosis were evident in the stomach pylorus or duodenum As already mentioned in approximately 40 per cent of cases with stenosis of the esophagus due to a corro ive similar cicatricial changes were also present in the stomach A number of these patients

observed in the non transplanted small gut (2, 37). No adaptation changes of the mucosal folds have been noted and no narrowing where the transplant traverses the artificial opening in the diaphragm, even during deep breathing, has been evident. The shorter transplants have been straight, the longer ones tortuous and curved. The passage of contrast media is usually immediate and free, without any puddling or delay.

Differing characteristics. The transplanted segment consisting of terminal ileum, ileo cecal valve and cecum had essentially the same appearances as in situ in the normal abdominal cavity. Just proximal to the ileocecal valve the mucosal folds were, however, oriented in a longitudinal parallel direction. Radiologic examination of this area was often difficult because of masking by the barium within the stomach behind it. It is thus satisfactorily viewed only during the initial stages of ingestion of barium in left lateral projections. The anastomosis appeared as a circular, smooth walled narrowing of the lumen. The possibility of the ileocecal valve functioning as the normal cardia has been discussed by SAPOTA. Without access to cineradiography equipment, an estimate of the function of the new "cardia" could be arrived at only indirectly from the secondary effects of its function.

In the JEZIORO operative technique, the cecum is anastomosed to a large opening in the anterior gastric wall near the lesser curvature. (Distal anastomosis, Figs 11, 13.) It was easily recognized as a broad based, dome like mass attached to the stomach with the terminal ileum and ileocecal valve situated at the apex of the dome. The cecal part has smooth internal walls, devoid of the rugae characteristic of the gastric mucosa, its attachment to the stomach is indistinct. Its size depends on the size of the part of the cecum utilized in the repair and on its degree of distension by contrast medium. The actual size encountered most often was that of a hen's egg, no time influenced changes in size occurred. The cecal part filled and emptied in the same manner and at the same rate as the stomach.

The transplanted jejunal segment exhibits essentially the same features that characterize it in situ in the abdominal cavity. The appearances of the mucosal folds depend on the function of the transplant at the time of the examination. The present surgical practice is to make the anastomosis to the stomach end to side, in the older, now obsolete, side to side method a part of jejunum could be observed hanging down posterior to the stomach. This pouch of the jejunum was found anastomosed to yet another intestinal loop in the Roux Y fashion or to end blindly, in the latter case it remained unchanged or sometimes gradually dilated. The development was thus similar to that observed in the neck in cases of side to end anastomosis between the true esophagus and the transplant and was probably caused by a retained content.



Fig 14 Coloplasty Barium remains in the reconstructed esophagus for over 4 hours

differ essentially from those reconstructed from segments of both the colon and the small bowel (see p 198) The lower parts of the colonic transplants however revealed changes that have been mentioned as indicating a degree of dysfunction i e slowing of the passage of the contrast medium, *deepening of* haustrations and retention of large amounts of contrast medium for four hours *or longer (Fig 14)* Where the transplanted colonic segment, particularly the intra abdominal part was relatively short and was anastomosed to the middle or *proximal* part of the stomach, the signs of dysfunction were *generally less marked* Gastro-esophageal reflux was however usually more marked (Fig 15)

Lengthening of the lower part of the transplanted colon and its anastomosing with the distal *part of the stomach* or with the gastric antrum facilitates the mechanisms that close the new cardia (*see* p 207) The lengthy and delayed passage of the contrast medium as well as *syphon like function* due to tortuosity of the segment however made the practical demonstration of the mechanism difficult

A diagnostic feature indicative of insufficiency of the new cardia is the absence of gas in the stomach This *valuable* sign is observed irrespective of whether the patient is fasting or not It has been noted in some 60 per cent of the cases in this group gastro-esophageal reflux occurred in 65 per cent of the cases

Delayed emptying, syphon like bends of the transplant and evidence of gastro-esophageal reflux appear to lead to later complications colitis of the reconstructed esophagus with or without ulceration ileus of the syphon like bends

had undergone gastric surgery in addition to esophageal reconstruction, various types of gastroduodenostomies and gastrojejunostomies had been performed. An extensive literature deals with this problem in more detail (18, 21).

Special attention was directed to the behaviour of the gas content of the stomach in the present material. An effort was made to correlate the amount of gas with the function of the reconstructed esophagus and cardia. These observations are not yet complete. Nevertheless it can be said that (1) the presence of gas in the stomach with the patient fasting is evidence of correct functioning of the reconstruction, (2) absence of gas on an empty stomach and particularly after ingestion of food, suggests either dysfunction of the passage or the presence of gastro-esophageal reflux.

Patients who have been subjected to various colonic transplant operations did not, as a rule, complain of any symptoms referable to the part of the large intestine remaining in situ. Bowel movements were usually regular and normal. The part of the colon remaining in situ was shortened and its circumference reduced although with anti-operistaltic transplants, the remaining part of the large bowel was generally somewhat lengthened. Generally speaking, the radiologic appearance of the remaining colon failed to offer any information as to which segment had been used for transplantation, neither was it possible to say whether the transplant had been arranged iso- or anisoperistaltically in the mediastinum.

Twenty four hours after ingestion of contrast medium the new esophagus, stomach and small intestine were as a rule empty and the contrast medium could be observed in the part of the colon remaining in situ. The radiologic appearance for the latter did not differ from the otherwise normal colon (34) apart from the shortening and the lessening of its circumference mentioned. No correlation has been noted between the depth of the haustrations of the transplanted colon and of those parts of the colon remaining in situ.

Colon transplantation. Esophageal reconstruction utilizing a segment of the *colon is no longer performed. Such a procedure is* technically easy and its initial complications few but late complications and dysfunctions are, however, frequent (9, 17, 19, 24, 27). Segments of colon are today combined with segments of ileum or jejunum. (See under coloileocecoplastics and colojejunoplastics.)

A total of 44 cases that had coloplastics have been examined, most of these in the period 1959—1964. Only isolated cases have been met with since. The average length of the reconstructed esophagus was 37 cm, occasionally up to 41 cm. A tendency towards elongation, tortuosity, distortion, and a trend of the transplants to lie against the dome of the right diaphragm was evident in many of these cases. The upper and middle parts of the transplants did not



Fig 16 Ileocecoplasty Tortuous course of the reconstructed esophagus

was always of considerable length with marked tortuosity in its middle and distal parts (Fig 16) This was due to the operative impossibility of straightening out the proposed transplant segment of small gut together with its mesentery without endangering its blood supply The length of the passage is thus increased but provided that peristaltic function is unimpaired, this per se is of little importance The speed of the passage is adequate or good and emptying is not delayed (24) there is no puddling of barium Only a few traces of the medium remained within the deeper mucosal folds at the end of 30 minutes and none at all were observed at 90 minutes

The morphology and the function of the small gut gastric anastomosis including the new cardia have already been considered

Results and Discussion

A detailed history was always obtained of symptoms that could possibly be related to dysfunction of the esophageal reconstruction Most cases with colo ileocecoplasty and ileocecoplasty as well as the majority of those with coloplasty and secondary jejunal interposition or jejunoplasty had no symptoms whatsoever



Fig. 15. Coloplasty. Trendelenburg position. Reflux evident.

and frequent symptoms most likely due to reflux (6, 9, 19). These sequelae have necessitated resection of the lower part of the transplanted colon and its replacement by a jejunal segment in 8 cases in this group (see Table).

Small gut plasty. General use of retrosternal ileocecoplasty or jejunoplasty has been discontinued, not because of late complications but by reason of the technical surgical difficulties and early complications (JEZIORO). To secure sufficiently long, sufficiently vascularized segments of small intestine is at times almost impossible. Consequently the method is useful only in selected cases and when short transplants can be used, i.e. between (a) the transplanted colon and the stomach, (b) the remnant after secondary resection of the lower part of the colon with the stomach (group B), and (c) the lower part of the true esophagus and the stomach in cases in which only the most distal part of the esophagus is stenotic (group F 3). Thirty five cases in this category were examined. The morphologic and physiologic characteristics of the small gut reconstructed esophagus usually did not differ from those of the non transplanted small gut in situ (2, 37), or from other parts of the gut used for transplantation purposes (groups A 1, A 2, B). The transplanted small intestine in these cases



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Prestenotic dilatation proximal to the anastomosis between the colon and small bowel has not been observed An anastomo is width of about one finger s breadth assures patency of the passage Retention of barium in the colonic segment above the anastomo is appears not to be due to disproportion between the larger colonic lumen proximally and the mall intestinal lumen distally, but rather to slowness of the colonic passage itself

Conclusions

The JEZIORO methods of esophageal reconstruction consisting of transplantation of a segment of the colon with the addition of a segment of jejunum are efficient and functionally adequate Reconstruction of the cardia achieved by the e means efficiently prevents e ophageal reflux

The radiologic appearance of the thoracic organs did not change apart from the presence of a gas-filled transplant in the middle part of the mediastinum The individual components of the multi segmental reconstruction retained their radiologic characteristics An exception was apparent in the proximal end of the colon segment which developed a longitudinal orientation of the mucosal folds this e ophagisation may be considered evidence of adaptation of the colon to its new role of rapid transport of food

Anisoperistaltic segments of the colon were free of barium within 30 minutes of its ingestion but i operistaltic colon segments were clear within 60 minutes (*groups* A 1 A 2 B) Traces and smears of barium could remain on the mucosa for two hours retention of barium within these time limits seems to be without significance E ophageal reconstruction with only the colon prolonged this retention time to *four hours or more*

The ileocecal valve seemed to assume the function *of the* normal cardia, it protected the reconstruction against the effects of gastro-esophageal reflux The cardiac valve *functions* were probably assumed by the action of indirect mechanisms where a jejunal *segment was used* The absence of valve function in this type in reconstruction with the colon only may cause late complications due to gastro-esophageal reflux

An evaluation of valve function of the *new cardia* is possible during routine radiologic examination in approximately half the cases (no such valve is present in coloplasty) Instillation of *barium through* a feeding gastrostomy (before its surgical closure) is necessary *to determine* whether reflux is present or not The presence of gas in an otherwi e empty stomach indicated a correctly functioning reconstruction its absence *suggested dysfunction*

Radiologic examination of the remainder of the colon in the abdomen following transplantation of a part revealed only shortening It was not possible

No gastro esophageal reflux was evident in any case with an ileocecal valve 'cardia' (groups A 1, D 1). The radiologic findings however failed always to correspond to the subjective condition. This was particularly so regarding the speed of the passage and retention of the medium in the large gut segments. The initial speed of passage was good in all cases examined in the erect position, emptying times following coloileoplasty and secondary colojejunoplasty were two hours at the most, whilst in cases in which coloplasty had been performed they averaged four hours or longer.

Evacuation times were probably influenced by the unpleasant taste and consistency of the barium emulsion. It was definitely observed that where barium impregnated bread rolls were employed, the emptying times were reduced on the average by a half. It should of course be kept in mind that one aspect of normal colonic function consists in the storage of fecal material, delay in the *emptying of the transplanted colon should be viewed in this light*. No great importance should consequently be assigned to the retention of greater or lesser amounts of contrast medium, or for that matter of food, in the transplanted colon for times of up to one to two hours. Patients who exhibit this phenomenon do not, as a rule, complain of discomfort.

A slow passage and retention of contrast medium are related to intestinal movements. Observations, although not yet complete, indicate the presence of peristalsis in the transplanted segments of the small intestine. Evidence of a slower, mixing type of movement in segments of the transplanted large gut also exists. *These movements are similar to those that occur in the undisturbed intra abdominal intestine*. 'Effective peristaltic mass movements' (motus colonis magnus), such as described in the physiologic literature (36), have not, however, been observed although it is possible that such mass peristalsis does exist. Long time exposure techniques with prohibitive radiation hazards would be necessary for its radiologic demonstration. According to the pertinent literature on the subject (32) the transport type movements of the colon are very slow and almost impossible to detect by the naked eye. Colonic mass movements on the other hand take place two to three times only in every 24 hours. Their detection *during a short radiologic observation period* would therefore be almost fortuitous, especially since only limited segments of the colon are under observation.

Secondary elongation of the transplant often occurred following an esophageal reconstruction that utilized the colon alone. This elongation assumed a tortuous course, mainly convex towards the right dome of the diaphragm, it caused syphon like curves and bends, disturbances in the passage and other complications. No such problems have been encountered during the four year follow up of cases operated on by the multiple segment techniques, where the colon formed only one, relatively short part of the reconstruction.

Prestenotic dilatation proximal to the anastomosis between the colon and small bowel has not been observed An anastomosis width of about one finger s breadth assure patency of the passage Retention of barium in the colonic segment above the anastomosis appears not to be due to disproportion between the larger colonic lumen proximally and the small intestinal lumen distally, but rather to slowness of the colonic passage itself

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to determine which part of the colon had been removed, neither was it possible to state whether the segment removed had been aligned iso- or anisoperistaltically in the mediastinum.

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The author takes this opportunity of thanking Prof. Zdzisław Jezioro for his help, encouragement and advice. He also expresses his indebtedness to Zbigniew Kubrakiewicz, T. Kaniowski and T. Marciniak for their corrections and suggestions. His brother M. Tuszewski translated the Polish manuscript and made the publication possible.

SUMMARY

The radiologic appearance and physiologic function of esophageal reconstructions were evaluated in 382 examinations performed in 118 cases. The Jezioro developed methods of reconstruction by transposing a segment of the colon with the addition of a part of the ileum and cecum or a segment of jejunum are satisfactory and functionally adequate. Such reconstructions of the cardia effectively prevent gastro-esophageal reflux.

ZUSAMMENFASSUNG

Das röntgenologische Erscheinungsbild und die physiologische Funktion der Wiederherstellung des Ösophagus wurden in 382 Untersuchungen an 118 Fällen festgestellt. Die von Jezioro entwickelten Methoden der Rekonstruktion mit Transposition eines Segmentes des Colon unter Zufügung eines Teils des Ileum und Caecum oder eines Segments des Jejunum sind zufriedenstellend und funktionell adäquat. Eine derartige Rekonstruktion der Cardia verhindert wirksam den gastro-ösophagealen Reflux.

RÉSUMÉ

Les auteurs ont étudié sur 382 examens faits dans 118 cas les aspects radiologiques et la fonction physiologique de reconstructions œsophagiennes. Les méthodes de reconstruction par transposition d'un segment colique avec adjonction d'une partie de l'iléon, du caecum et d'un segment jéjunal, mises au point par Jeziero, sont satisfaisantes et fonctionnellement adaptées. Ces reconstructions du cardia empêchent effectivement le reflux gastro-œsophagien.

REFERENCES

1. BATTERSBY J. G. Reconstruction of the upper gastrointestinal tracts with colon segments after esophagogastroectomy. Arch. Surg. 77 (1958) 376.
2. BERG H. H. Röntgenuntersuchungen am Innenrelief des Verdauungskanals. G. Thieme, Leipzig 1930.
3. BERMAN E. F. Cited by ROSSETTI.
4. BROSS W. i KOCZOROWSKI S. Chirurgia. cz. 2. p. 137. (In Polish.) PWN Wrocław 1952.

5 COCHRANE D Q ALMOND C H and SHUCART W A Experimental study of effects of barium and intestinal contents on peritoneal cavity Amer J Roentgenol 89 (1963) 883

6 FENNESY J J SPARBERG M and KIRSNER J B Early roentgen manifestation of mild ulcerative colitis and proctitis Radiology 87 (1966) 848

7 JEZIORO Z Wytworzenie sztucznego przełyku z krętego jelita (In Polish) Pol Przegl chir 30 (1958) 111

8 — Wytworzenie nowego przełyku z krętego jelita i kątnicy (In Polish) PZWL Warszawa 1960

9 — Chirurgiczne leczenie wstecznego odpływu treści żołądkowej do sztucznego przełyku wytworzonego z jelita grubego (In Polish) Pol Przegl chir 39 (1967) 774

10 — Wytworzenie przełyku z jelita grubego uszypułowanego na naczyniach okrężniczych lewych z wstawką z jelita krętego i kątnicy (In Polish) Pol Przegl chir 39 (1967) 809

11 — i DRAK J Wtórne uruchomienie cienkiego jelita przy rekonstrukcyjnym zabiegu wytwórczym przełyku (In Polish) Pol Przegl chir 26 (1954) 769

12 — und KUS H Retrosternale Oesophagoplastik aus dem Jejunum bei Kindern Zbl Chir 82 (1957) 425

13 — O zamostkowym przemieszczeniu cienkiego jelita w zabiegach wytwórczych przełyku Pol Przegl chir 29 (1957) 301

14 — — Experiences with retrosternal esophageal replacement employing jejunum or ileum Surgery 44 (1958) 275

15 — BERNAT M i JEZIORO I Operacje wytwórcze przełyku z jelita grubego z zastosowaniem wstawek usprawniających mechanizm wpustowy Pamiętnik XLIII Zjazdu Chirurg w Polskich Łódź 1966

16 — KUŚ H i DRAK J Zasługi chirurgów radzieckich w rozwoju i kształtowaniu się zabiegów wytwórczych przełyku Pol Tyg lek 10 (1955) 1283

17 ZIMMER Z i JEZIORO I Odległe wyniki czynnościowe sztucznego przełyku wytworzonego z jelita grubego Pamiętnik XLIII Zjazdu Chirurgów Polskich Łódź 1966

18 — — PIEGZA S i JEZIORO I Chirurgiczne leczenie współistniejących bliznowych zwężeń przełyku i żołądka po oparzeniu środkiem żrącym Pol Przegl chir 38 (1966) 733

19 — BERNAT M PIEGZA S i ZIMMER Z Krwotoczne trawienne zapalenie przełyku wytworzonego z jelita grubego Pol Przegl chir 39 (1967) 1

20 KUS H O współczesnych próbach wytwórczych zabiegów na przełyku z użyciem protez z mas plastycznych i przeszczepów tkankowych Pol Przegl chir 30 (1958) 1021

21 — Die chirurgischen Probleme der Magenverletzung mit besonderer Berucksichtigung der Magenstenose Chirurg 31 (1960) 360

22 LEB A Die Rontgenuntersuchung des resezierten Magen mit Eiweiss- und Fett Barium kernen Fortschr Rontgenstr 75 (1951) 106

23 LORTAT J J L Oesophagoplastie isopéristaltique trans-thoraco-médiastinale avec le colon transverse Mém Acad Chir 77 (1951) 586

24 MILEWICZ Z Przełyk sztuczny w obrazie rentgenowskim (In Polish) Pol. Przegl radiol 29 (1965) 41

25 MONTENEGRO E and CUTAIT E Construction of a new esophagus by means of the transverse colon and its application for caustic atresia carcinoma and varices of the esophagus Surgery 44 (1958) 785

26 MULLER BOTHA G S The gastro-oesophageal junction J and A Churchill Ltd London 1962
27 NARDI G L and GLOTZER D J Anastomotic ulcer of colon following colonic replacement of esophagus Ann Surg 152 (1960) 10
28 PETROV B A Retrosternal artificial esophagus from jejunum and colon Surgery 45 (1959) 890
29 — Retrosternal artificial esophagus Brit J Surg 46 (1959), 516
30 Rontgenkontrastmittel Ciba, Chemie AG, Schaffhausen
31 ROSSETTI M Die operierte Speiserohre Pathologie Klinik und Rontgenologie G Thieme, Stuttgart 1963
32 SCHINZ H R, BAENSCH W E, FROMMHOLD W et coll Lehrbuch der Rontgendiagnostik Band 3, p 3341 G Thieme, Stuttgart 1952
33 SOUTTAR Cited by ROSSETTI
34 STEVENSON C A Clinical roentgenology of the colon Amer J Roentgenol 96 (1966), 275
35 STOICA T und POENARU D Beitrag zur Untersuchung der Magenentleerung nach Gastrectomie Fortschr Rontgenstr 100 (1964) 579
36 SZABUNIEWICZ B Zarys fizjologii czlowieka (In Polish) PZWL Warszawa 1960
37 ZABOKRZYCKI J Radiodiagnostyka jelita cienkiego (In Polish) PZWL, Warszawa 1954
38 SAPOTA J Badanie czynnościowe zastawki krętniczo kątniczej jej przydatność w wytwarzaniu sztucznego wpustu (In Polish) Pol Przegl chir 37 (1965) 311

FROM THE DEPARTMENT OF RADIOLOGY ST THOMAS HOSPITAL LONDON ENGLAND

ANGIOMA OF THE KNEE DEMONSTRATED BY ANGIOGRAPHY AND ARTHROGRAPHY

Report of a case

by

M LEA THOMAS and M R ANDRESS

Angiomas rarely involve joints STEVENS et coll (1969) found 96 cases reported in the literature most often in the knee and added one further case also affecting the knee

Articular angiomas are often diagnosed only after a long delay (KARLHOLM & STJERNSWARD 1963 MILLER 1969) and then in many cases only after exploration of the joint The radiologic investigations even including angiography and arthrography are often negative as in the case reported by STEVENS *et coll*

This paper describes the radiologic appearances of an angioma demonstrated by angiography and arthrography

Case report

A boy aged 8 years presented with intermittent painful swelling of the right knee since the age of 1 year These episodes were becoming more frequent

On examination he walked with a limp and the right leg was longer than the left There was palpable synovial thickening over the medial side of the knee joint A cutaneous haemangioma of the right buttock and leg was *present*

Films of the legs showed more advanced ossification of the right patella and increased right femoral length

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26 MULLER BOTHA G S The gastro oesophageal junction J and A Churchill Ltd London 1962
27 NARDI G L and GLOTZER D J Anastomotic ulcer of colon following colonic replacement of esophagus Ann Surg 152 (1960) 10
28 PETROW B A Retrosternal artifical esophagus from jejunum and colon Surgery 45 (1959) 890
29 — Retrosternal artificial esophagus Brit J Surg 46 (1959) 516
30 Röntgenkontrastmittel Cilag Chemie AG, Schaffhausen
31 ROSSETTI M Die operierte Speiseröhre Pathologie Klinik und Röntgenologie G Thieme, Stuttgart 1963
32 SCHINZ H R, BAENSCH W E, FROMMHOLD W et coll Lehrbuch der Röntgendiagnostik Band 3, p 3341 G Thieme, Stuttgart 1952
33 SOUTTAR Cited by ROSSETTI
34 STEVENSON C A Clinical roentgenology of the colon Amer J Roentgenol 96 (1966) 275
35 STOICA I und POPESARU D Beitrag zur Untersuchung der Magenentleerung nach Gastrectomie Fortschr Röntgenstr 100 (1964) 579
36 SZABUNIEWICZ B Zarys fizjologii człowieka (In Polish) PZWL Warszawa 1960
37 ZABOKRZYCKI J Radiodiagnostyka jelita cienkiego (In Polish) PZWL Warszawa 1954
38 SAŁOTA J Badanie czynnościowe zastawki krętniczo kątniczej jej przydatność w wytwarzaniu sztucznego wpustu (In Polish) Pol Przegl chir 37 (1965) 311



Fig 2 Positive contrast arthrography a) A p view b) Lateral view Angioma outlined in medial side of knee joint and suprapatellar pouch

In our patient the angioma involved the structures around the knee and extended into the knee joint itself The presence of a cutaneous haemangioma elsewhere assisted in the clinical diagnosis

The accelerated epiphyseal development and increased length may have been due to venous stasis as suggested by others (BARIETY et coll 1967 LACROIX 1951 MALAN & PUGLIONISI 1964 MYERS & JANES 1955 SERVELLE 1945)

TOMASSINI (1966) presented the angiographic findings in a patient with a congenital arteriovenous malformation within the knee both preoperatively and after successful removal of the lesion In our patient there was no evidence of arteriovenous shunting and the appearances were those of essentially a venous angioma The examination was valuable in confirming the diagnosis and in indicating the extent of the lesion The positive contrast arthrography showed more clearly the exact relationship of the angioma to the joint space thus influencing the surgical approach and the successful removal of the malformation

As far as we are aware there has been no report of an intra articular angioma demonstrated by arthrography KARLHOLM & STJERNSWARD (1963) and STEVENS et coll (1969) each reported a case in which arthrography had been carried out but in both the examinations were negative



Fig. 1. Angiography. a) Normal arterial phase. b) A.p. and c) lateral views in the venous phase showing the angioma.

Right femoral angiography was performed by cannulation of the femoral artery in a descending direction. Fifteen millilitres of Conray 60 % were injected and a series of films taken in the a.p. and lateral projections using an AOT changer. Twelve films were exposed at a rate of 3 per second followed by 4 films exposed 1 every 2 seconds in each plane. The arterial phase was normal but in the venous phase there was pooling of contrast medium in the region of the knee (Fig. 1). The examination revealed that the angioma extended into the medial side of the knee joint and into the suprapatellar pouch.

To provide more precise information of the relation of the malformation to the joint a positive contrast arthrography was carried out by the injection of 10 ml Urografin 30 % into the joint space and films taken in a.p., lateral and oblique projections. This examination showed soft tissue masses in the medial side of the joint space posteriorly and in the suprapatellar pouch (Fig. 2).

The radiologic investigations thus confirmed the clinically suggested angioma of the knee joint and this was successfully excised.

Discussion

Angiomas of joints may be juxta-articular or intra-articular or both (Jacobs & Lee 1949). The juxta-articular type involves the peri-articular structures, particularly the quadriceps muscle, and the tumour is always palpable; it does not involve the capsular or synovial membranes. The intra-articular type may occupy any part of the synovial cavity and may cause serosanguinous effusions

FROM THE DEPARTMENT OF RADIOLOGY, ST THOMAS HOSPITAL LONDON ENGLAND

PEYRONIE S DISEASE DEMONSTRATED BY CAVERNOSOGRAPHY

by

M LEA THOMAS and D H ROSE

Peyronie s disease is a condition of unknown aetiology in which fibrous plaques develop in the corpora cavernosa The patients complain of painful erection followed by impotence and hard plaques can be palpated along the shaft of the penis Recognition of the disease clinically is *not difficult*, but palpation seldom reveals the full extent of the lesion

Systemic treatment in this condition includes oral vitamin E (SCARDINO & SCOTT 1949) and the anti fibrosis drug potassium aminobenzoate (ZARAFONETIS & HORRAX 1959) Local therapy consists of steroids (CHESNEY 1963 DESANCTIS & FUREY 1967 HAMILTON & SWANN 1967) radiation therapy (DUGGAN 1964 HICKMAN 1967) or plastic surgery (FOGH ANDERSON 1957, LOWSLEY & BOYCE 1950) including the insertion of a *prosthesis* WILLIAMS & THOMAS (1968 1970) consider that spontaneous remissions occur in the majority of cases without treatment

If local treatment is considered advisable an accurate anatomic delineation of the fibrous plaques and of the general state of the corpora cavernosa is desirable This can be achieved by contrast medium examination of the erectile tissue of penis — cavernosography

Submitted for publication 17 May 1971

SUMMARY

The angiographic and arthrographic findings of an angioma involving the knee joint are presented

ZUSAMMENFASSUNG

Die angiographischen und arthrographischen Befunde eines Angioms bei dem das Kniegelenk befallen war, werden gegeben

RÉSUMÉ

Présentation des signes angiographiques et arthrographiques d un angiome de l articulation du genou

REFERENCES

BARIETY M SERVELLE M POULET J et RUFF I Angiomes veineux et dysplasies vasculaires congénitales des membres Bull Soc méd Hop Paris 118 (1967) 39

JACOBS J F and LEE F W Hemangioma of the knee joint J Bone Jt Surg 31 A (1949) 831

KARLHOLM S and STJERNSWARD J Hemangioma of the knee joint Acta orthop scand 33 (1963) 303

LACROIX P The Organisation of bones J and A Churchill Ltd London 1951

MALAN E and PUGLIONISI A Congenital angiodysplasias of the extremities (Note I Generalities and classification venous dysplasias) J cardiovasc Surg 5 (1964) 87

MILLER A Idiopathic joint apoplexy (communication) Arthr and Rheum 12 (1969), 646

MYERS J T and JANES J M Comprehensive surgical management of cavernous hemangioma of the lower extremity with special reference to stripping Surgery 37 (1955) 184

SERVELLE M La veinographie va t elle nous permettre de démembrer le syndrome de Klippel et Trénaunay et l hémangiectasie hypertrophique de Parkes Weber? Presse méd 53 (1945), 353

STEVENS J KATZ P L ARCHER F L and McCARTY D J Synovial hemangioma of the knee Arthr and Rheum 12 (1969) 647

TOMASSINI N Emartro da fistole artero venose congenite della capsula articolare del ginocchio (In Italian) Chir ital 18 (1966), 595

saline was injected to ensure that the needle was lying in a corpus and not subcutaneously

A mall rubber catheter was gently tightened around the ba e of the penis The contrast medium Urografin 60 %, was slowly injected under screen control into the corpora cavernosa and films were taken in the p a lateral and oblique projections Approximately 20 ml of contrast medium were required

Findings The examination showed a filling defect approximately 2 cm long extending deeply into the lateral aspect of the left corpus cavernosum, and a shallow irregularity along the lateral side of the right corpus cavernosum (Figure b and c) These changes were considered to represent fibrous plaque formation in the penile shaft

Discussion

Our method of investigating Peyronie s di ease radiologically is similar to that de cribed by Hamilton & Swann (1967) We have found however, that better filling of the corpora is achieved by applying a rubber tourniquet to the ba e of the penis This prevents much of the contrast medium passing into the pudendal veins (Figure) If the injection is performed slowly under screen control there hould be no danger of overfilling the corpora and thereby missing a plaque We agree with Edling & Leander (1964) that it is unnecessary to inject both corpora cavernosa as recommended by Fetter et coll (1963) since both sides fill equally and simultaneously with contrast medium when one corpus is injected General anaesthesia is only indicated in anxious patients Local anaesthesia can be induced by injection of 1 ml of 2 % lignocaine into the skin fascia and corpus cavernosum on one side before the introduction of contrast medium Injection of the medium itself Urografin 60 % is safe and painless

In the normal penis contrast medium completely fills the corpora cavernosa o that two smooth longitudinal bands of tissue are seen with a uniformly narrow septum between them The fibrous plaques of Peyronie s disease appear as filling defects in the mooth contour lying laterally along the shaft of the penis dorsally or in the septum

Hirtl (1962) stated that palpation of the penile plaques frequently fails to reveal the full extent of the condition However demonstration of the site and size of these plaques by cavernosography provides an accurate and objective delineation of the disease process This is u eful before any local treatment whether it be injections of hydrocortisone, radiation therapy or surgery Further progress of the condition, with or without treatment may be followed objectively



a) I a projection Without tourniquet No filling of corpora and contrast medium in pudendal veins b) I a projection With tourniquet Corpora well filled with contrast medium Fibrous plaques on both sides of the penile shaft (→) c) Oblique projection showing dorsal extension of left sided plaque (→)

This paper describes a method of cavernosography which was used in a patient with Peyronie's disease before surgical treatment

Case report

A man aged 57 presented with partial impotence for 4 months He was otherwise well On examination hard nodules larger on the left than the right were palpated on the shaft on the penis

Treatment with vitamin E (Tocopherol) was instituted for 3 months followed by potassium aminobenzoate (Potaba) This treatment was ineffective

When seen again 11 months later the patient had been totally impotent for 9 months and complained of pain in the penis There was little change in the condition clinically although the nodule on the right side of the penis had enlarged

Cavernosography was performed with a view to surgical treatment A silastic Pearman penile implant was inserted

Method The investigation was performed under general anaesthesia on a screening table equipped with television and an automatic exposure control and with the patient in the supine position

A 21 gauge, 40 mm needle with polythene connecting tube was attached to a syringe containing 10 ml of normal saline The needle was inserted into the shaft of the penis just proximal to the glans on the dorsal surface The

saline was injected to ensure that the needle was lying in a corpus and not subcutaneously

A small rubber catheter was gently tightened around the base of the penis The contrast medium Urografin 60 %, was slowly injected under screen control into the corpora cavernosa and films were taken in the p a , lateral and oblique projections Approximately 20 ml of contrast medium were required

Findings The examination showed a filling defect approximately 2 cm long extending deeply into the lateral aspect of the left corpus cavernosum, and a shallow irregularity along the lateral side of the right corpus cavernosum (Figure b and c) These changes were considered to represent fibrous plaque formation in the penile shaft

Discussion

Our method of investigating Peyronie s disease radiologically is similar to that described by HAMILTON & SWANN (1967) We have found however that better filling of the corpora is achieved by applying a rubber tourniquet to the base of the penis This prevents much of the contrast medium passing into the pudendal veins (Figure) If the injection is performed slowly under screen control there should be no danger of overfilling the corpora and thereby missing a plaque We agree with EDLING & LEANDER (1964) that it is unnecessary to inject both corpora cavernosa as recommended by FETTER *et coll* (1963) since both sides fill equally and simultaneously with contrast medium when one corpus is injected General anaesthesia is only indicated in anxious patients Local anaesthesia can be induced by injection of 1 ml of 2 % lignocaine into the skin fascia and corpus cavernosum on one side before the introduction of contrast medium Injection of the medium itself Urografin 60 %, is safe and painless

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HIRTL (1962) stated that palpation of the penile plaques frequently fails to reveal the full extent of the condition However demonstration of the site and size of these plaques by cavernosography provides an accurate and objective delineation of the disease process This is useful before any local treatment whether it be injections of hydrocortisone radiation therapy or surgery Further progress of the condition with or without treatment, may be followed objectively

In the patient described the purpose of this investigation was pre-operative assessment of the extent of the disease Localised surgery in an attempt to remove the fibrous plaques was contemplated before the examination revealed the wide distribution of these lesions Hence the silastic implant was inserted

SUMMARY

The radiologic investigation of Peyronie s disease by cavernosography is described Its application is discussed and illustrated by a case report

ZUSAMMENFASSUNG

Die radiologische Untersuchung der Peyronie schen Krankheit mittels Cavernosographie wird beschrieben Ihre Anwendung wird besprochen und durch eine Fallbeschreibun illustriert

RÉSUMÉ

Description de l examen radiologique de la maladie de La Peyronie par cavernosographie Les auteurs étudient son application et en presentent un cas

REFERENCES

CHESNEY J Plastic induration of the penis Peyronie s disease Brit J Urol 35 (1963) 61

DESANCTIS P N and FUREY JR C A Steroid injection therapy for Peyronie s disease a 10 year summary and review of 38 cases J Urol 97 (1967) 114

DUGGAN H E Treatment of Peyronie s disease J Urol 91 (1964) 672

EDLING N P G and LEANDER G Contrast medium examination of erectile tissue of the penis (Cavernosography) Urol int 18 (1964) 293

FETTER T R YUNEN J R and DODD G Application of cavernosography in the diagnosis of lesions of the penis Amer J Roentgenol 90 (1963) 169

FOCH ANDERSON P Surgical treatment of plastic induration of the penis (Peyronie s disease) Acta chir scand 113 (1957) 45

HAMILTON R W and SWANN J C Corpus cavernosography in Peyronie s disease Brit J Urol 39 (1967) 409

HICKMAN B T Radiologic Seminar 58 Peyronie s disease J Miss med Ass 8 (1967), 76

HIRTL H Plastic penile induration Urol int 13 (1962) 1

LOWSLEY O A and BOYCE W H Further experiences with an operation for the cure of Peyronie s disease J Urol 63 (1950) 888

SCARDINO P L and SCOTT W W The use of tocopherols in the treatment of Peyronie s disease Ann N Y Acad Sci 52 (1949) 390

WILLIAMS J L and THOMAS G G The natural history of Peyronie s disease Proc Roy Soc Med 61 (1968) 876

— — The natural history of Peyronie s disease J Urol 103 (1970) 75

ZARAFONETIS C J and HORRAX T M Treatment of Peyronie s disease with potassium para aminobenzoate (Potoba) J Urol 81 (1959) 770

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LOCAL TOXIC EFFECTS OF ANAESTHETICS AND CONTRAST MEDIA IN URETHROGRAPHY

by

S E SORENSEN

Retrograde urethrography has assumed the rank of a routine roentgen diagnostic method that provides valuable information about the normal and pathologic conditions of the male urethra

The commonly used technique is the one described by KNUTSSON (1929 1935) The contrast medium is injected manually through the the urethral orifice To minimize discomfort during the examination due to irritation of the urethral mucosa a local anaesthetic (Xylocain Gel or Carbocain Throat Gel) is injected before the medium The examination is usually carried out in conjunction with an examination of the urinary bladder by the double contrast method described by BARTLEY & HELANDER (1960) and then as the final part of the examination Sometimes however only retrograde urethrography is performed especially in pathologic conditions of the anterior urethra Serious sequelae often follow retrograde urethrography (NILSSON personal communication) Plastic surgeons (e g BREINE personal communication) demand a time lapse of at least a week from the roentgen examination before operation because of the oedema of the urethral and bladder mucosa caused by the examination

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Table 1

Pharmacologically active substances in the solutions examined

Xylocain Gel	Xylocain 2 %
	Methylcellulose C 1
Carbocain Thesit Gel	Carbocain 1.5 %
	Thesit 1.0 %
	Carbocain Thesit (1.5 + 1.0 %)
	Methylcellulose Gel
Perjodal S	Diodon Dietanolamin (125 mg I/ml)
	Dextran (viscosity 130 cSt)
Perjodal U	Diodon Dietanolamin (175 mg I/ml)
	Dextran (viscosity 400 cSt)

When assessing the value of urethrography as a method of investigation of the lower urinary tract due regard must be paid to the complications that may arise. It is known that fluids injected into the urethra may pass through lesions in the mucosa into the submucosal tissue and further into the venous system. Not infrequently this has been observed in urethrography as contrast filling of the corpus cavernosum urethrae or the surrounding veins — urethro-cavernous reflux. MORALES & ROMANUS (1952) gave the frequency of this complication as 5 %. KNUTSSON observed reflux in 4 cases out of a series of 154 cases examined (3 %) and LIDEN (1945) reported 12 cases out of 240 (5 %). BENTZEN (1960) found the incidence to be 4.3 % in 161 cases of urogenital tuberculosis and 10 % in a control series of 30 cases. This rather high frequency of clinical sequelae of accidental penetration of solutions into the tissue and vessels of the corpus cavernosum urethrae and accompanying tissue injury suggests further investigation of their cause. The experimental model earlier described by BRANEMARK et coll. (1969) and SORENSEN (1971) with deposition of the drugs directly into the tissue of the cheek pouch of the hamster appeared to be an adequate method for examining the tissue toxicity of the local anaesthetics and contrast media used in retrograde urethrography.

Material and Method. The following local anaesthetics and contrast media were investigated: (1) Xylocain Gel (Astra, Sodertalje), (2) Carbocain Thesit Gel (Bofors Nobel Pharma, Molndal) and (3) Perjodal S and Perjodal U (Pharmacia, Uppsala).

These media as presented commercially and used clinically consist of local anaesthetics in a methylcellulose gel and contrast media in a dextran solution to increase viscosity. Each accordingly consists of more than one pharmacologically active substance, the toxicity of which was investigated (Table 1). The solutions

Table 2

Solutions examined and number of experiments

	No of experiments
Xyloca n C 1	10
Xyloca n 2	10
Methylcellul se Gel	6
C rl ocain Thesat C el	12
Carboca n 1 5	10
Th at I a	10
C bocain Thesat (1 5 + 1)	10
M thylcellulose Cel	8
I erjodal S	7
Perjodal U	10
D odon D etanolamin 125 mg I/ml	19
D don D etanolam n 175 mg I/ml	10
D xtran 130 cSt	8
D xtran 400 cSt	8

examined and the number of experiments performed are listed in Table 2 The experimental procedure has been de cribed in detail (BRANEMARK et coll So RENSEN) and will therefore be only briefly mentioned

Hamsters weighing about 100 g were anaesthetized with Nembutal 30 mg/kg i m The cheek pouch was everted and exposed over a glass plate so that a proper conden or system could be u ed for transillumination The cheek pouch was irrigated with Tyrode s solution at a constant temperature of 37° C with the body temperature maintained this is important as the circulation in the cheek pouch is en itive to dehydration and change in temperature

A standardized do e of 0 05 ml of the drug to be examined was deposited into the ti sue in the upper layer of the everted cheek pouch with a fine needle The distance between each ite of injction was about 10 mm Changes in the microcirculation were then examined in a modified Leitz intravital micro cope and changes in corpuscular flow velocity were determined in a selected small venule by a comparative optic-electronic method (BRANEMARK & JONSSON 1963) Fifteen minutes after the depo ition of the drugs in o the ti sue 1 5 ml of Evan s blue were injected intravenously into one of the hamster s hind legs Increa e in microva cular permeability cau ed by the olut ons injected was then determined by the method described by SORENSEN from the mea urement of the inten ity of

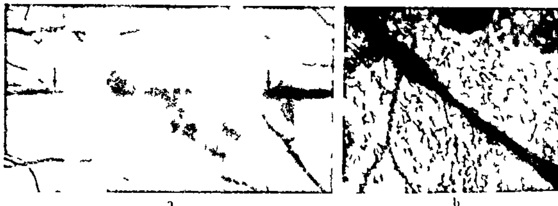


Fig. 1. Segmental arteriolar constrictions caused by a) Diodone and b) Xylocain. Location of constricted segment (→) and direction of flow (↔). × 10 (a), × 150 (b).

the blue staining in the deposit area. After application of the test substance the cheek pouch was observed and the microvascular permeability registered for up to 5 hours. It was not considered feasible to continue the observation for more than this time, the peripheral circulation of the animal is not optimal after so long a period of anaesthesia and furthermore a varying degree of oedema of the tissue develops after prolonged eversion and immobilisation of the cheek pouch.

Results

Xylocain and vehicle

Xylocain Gel. After deposition of the solution into the tissue the flow velocity almost immediately slowed down, first in the small venules of 10 to 30 μ diameter, secondly in the capillaries, then in the larger venules (diameter 30 to 80 μ) and finally in the arterioles of 20 to 50 μ diameter. The flow was unchanged in the marginal zone of the deposit area as in the larger venules and arterioles crossing the deposit area. The flow ceased completely in the small venules, capillaries and small arterioles after a period of two to four minutes, marked segmental contractions were noticed in the marginal arterioles (Fig. 1 b). The boundaries of the corpuscular elements of the blood appeared more distinct during the retardation of flow after application of the medium and the blood became coarse and granular in appearance, it appeared more or less structureless and homogeneous with severe deformation of the corpuscular elements during the circulatory standstill. The recovery of the microcirculation first appeared in the periphery of the deposit area and then spread towards the centre, the time required for restitution of flow velocity to original values is indicated in Fig. 2. The corpuscular flow failed to reach original velocity values in 4 out of 10

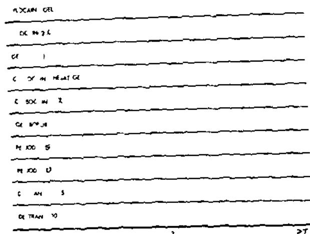


Fig 2 Time interval between application of media injected into the tissue and return of microvascular flow velocities

experiments suggesting more serious damage to the microcirculation After total or partial restitution of the circulation the vessels presented signs of toxic reaction *viz* and increasing number of granulocytes and single white thrombi adhering to and sliding along the vessel walls as well as an increasing number of white emboli passing through the vessels Blue staining of the whole deposit area was registered in four experiments and its intensity determined (Fig 3) Only punctate stained areas around small venules were evident in four exeprıments no demonstrable abnormality in the microvascular permeability was present in the remaining two experiments

Xylocain 2 % The application of Xylocain 2 % caused the flow in the microvessels immediately to slow down as described above in 7 of the 10 experiments The flow velocity in 3 cases increased for a short period at 3 to 5 minutes after the application and then slowed down again A general arrest in the flow occurred at 5 to 10 minutes in all experiments in all small venules capillaries and small arterioles Marked segmental contractions were noted in the marginal arterioles and venules as well as in the larger venules and arterioles with an intact flow over the deposit area After a period of 120 to 180 minutes the circulation in the whole deposit area partly recovered A characteristic feature in the microcirculation after the application of Xylocain 2 % was that many small venules with totally blocked circulation were filled with brilliantly red structureless blood The microcirculation recovered in only a few of these small venules during the observation period of 5 hours

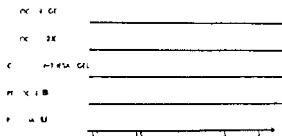


Fig. 3. Increase in capillary permeability. The abscissa indicates difference in light intensity between the surrounding region and deposit area measured in colour photographs of the cheek pouch of the hamster with a micro-ammeter.

Intense blue staining of the tissue in the whole deposit area was evident after restitution of the flow velocity in all the experiments (Figs 3 and 5).

As in the experiments with Xylocain Gel an increased number of granulocytes as well as white thrombi and emboli could be demonstrated in the microvessels after restitution of flow.

Methylcellulose Gel (Astra) caused immediately decreased flow velocity in small venules, capillaries and precapillary arterioles resulting in local circulatory standstill after 2 to 5 minutes. Any effect upon the flow in the larger venules (30 to 80 μ) or arterioles (diameter 20 to 50 μ) crossing the deposit area or marginally in the area was never demonstrated.

The transparency of the tissue increased in the deposit area with the blood becoming coarse and granular in appearance during the period of decreased flow and remaining so for the period of circulatory standstill. The flow velocity in all experiments had returned to original values after a period of 30 to 90 minutes with an increased number of white cells and many thrombi sliding along the vessel walls to indicate a toxic influence on the tissue. Increased permeability never occurred after the application of Methylcellulose Gel.

Carbocain Thesat and vehicle

Carbocain Thesat Gel. The microvascular flow reaction after the application of Carbocain Thesat Gel was an immediate reduction in flow velocity and at 2 to 5 minutes a complete arrest in corpuscular flow. The sequence of events was as earlier described with the reaction first occurring in the small venules, secondary in the capillaries, then in smaller arterioles and finally in larger arterioles and venules. During the period of reduced flow velocity the blood appeared coarse and granular.

A special feature after the application of Carbocain Thesat Gel was that after a period of 10 to 30 minutes haemolysis was recorded in 6 of the 12



a b

Fig 1 a) Venule with microthrombi after application of Dextran 400 cSt Location of microthrombi at endothelial wall (→) and direction of flow (white arrow) b) *Platelet thrombus* formed in a venule located in the marginal zone of a tissue area in which Carbocain Thesat (1 5 + 1) was deposited. Location of thrombus (→) Platelet aggregates were at times released from the wall adhering thrombus joining the circulating blood as microemboli × 700

experiments This was localized to small circumscribed areas in 4 cases and in 2 cases extensive areas of haemolysis and red staining of the tissues were demonstrated (Fig 5)

The microcirculatory flow velocity returned to original values in only 4 cases The time lapse from application of the medium to restitution of flow velocity is indicated in Fig 2 Areas with arrest of the microcirculation were observed during the whole observation period in the remaining 8 cases The microcirculation in the regions of the deposit area with a partly restituted flow was severely damaged this was evidenced by decreased flow velocity the formation of thrombi adhering to the vessel walls and hindering the flow and an increased number of granulocytes white thrombi and emboli along the walls

An evaluation of the blue staining in the deposit areas where the flow velocity was restituted to initial values appears in Fig 3 Marked segmentary contractions were evident in the arterioles and venules after total or partial restitution of flow These were also observed in the marginal part of the deposit area during the whole experimental period

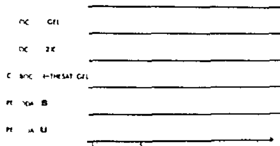


Fig 3 Increase in capillary permeability The abscissa indicates difference in light intensity between the surrounding region and deposit area measured in colour photographs of the cheek pouch of the hamster with a microammeter

Intense blue staining of the tissue in the whole deposit area was evident after restitution of the flow velocity in all the experiments (Figs 3 and 5)

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Fig 4 a) Venule with microthrombi after application of Dextran 400 cSt Location of microthrombi at endothelial all (→) and direction of flow (white arrow) b) Platelet thrombus formed in a venule located in the marginal zone of a tissue area in which Carbocain Thesat (1 5 + 1) was deposited Location of thrombus (→) Platelet aggregates were at times released from the all adhering thrombus joining the circulating blood as microemboli × 700

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The microcirculatory flow velocity returned to original values in only 4 cases The time lap e from application of the medium to restitution of flow velocity is indicated in Fig 2 Areas with arrest of the micro irculation were observed during the whole ob ervation period in the remaining 8 cases The microcirculation in the regions of the depo it area with a partly restituted flow was severely damaged this was evidenced by decrea ed flow velocity the formation of thrombi adhering to the ves el walls and hindering the flow and an increased number of granulocytes white thrombi and emboli along the walls

An evaluation of the blue staining in the depo it areas where the flow velocity was restituted to initial values appears in Fig 3 Marked segmentary contractions were evident in the arterioles and venules after total or partial restitution of flow The e were al o observed in the marginal part of the deposit area during the whole experimental period

Carbocain Thesat (1.5 % + 1 %). The deposition of this solution was followed by an immediate slow down of the flow velocity in the microvessels and after 0.5 to 1 minutes arrest of the microcirculation in the whole area was recorded. A faint spotted pink tinge appeared in 7 cases after a period of 10 to 30 minutes and extensively in the whole deposit area in 3 cases as an indication of haemolysis of the red blood cells. This directly observed phenomenon (Fig. 5) was confirmed microscopically.

In only one case did the microcirculatory flow recover to a nearly initial value whereas in all other cases the microcirculation was severely damaged, the circulation was intact only in some large vessels crossing the deposit area or in small demarcated areas with microvascular structure consisting of units of arteriole, short capillary and venule. Segmental contractions with an increased number of granulocytes adhering to the vessels walls as well as thrombus formation were evident in the vessels with more or less restored circulation (Fig. 4 b).

Blue staining in the deposit area as an indication of increased capillary permeability could not be used as a consequence of the damage to the microcirculation caused by Carbocain Thesat, only in the marginal zone of the deposit area could staining be observed. The physical prerequisite, a certain perfusion pressure, for escape of the protein bound Evan's blue into the tissues probably did not exist in those areas with no or more or less damaged microcirculation.

Carbocain (1.5 %). The deposition of this solution in the cheek pouch resulted in 3 out of 10 cases in increased flow velocity. This condition was succeeded after 5 to 10 minutes by a decrease in the flow velocity that at 15 to 30 minutes terminated in an arrest of the microcirculation. The flow velocity in the remaining 7 cases decreased almost immediately and ceased entirely at 5 to 15 minutes. The sequence of events in the microvessels was as described (page 228).

The flow at 120 to 180 minutes had recovered its initial values except in single small venules. Segmental contractions were observed, granulocytes and single white thrombi along the vessel walls as well as emboli were also just evident.

A characteristic feature was a milky white appearance of the tissue. Blue staining of the tissue in the deposit area appeared in none of the experiments after restitution of flow. No disturbance in microvascular permeability as determined by the technique could thus be demonstrated.

Thesat 1 % produced immediately reduced flow velocity at 0.5 to 1 minute resulting in its complete arrest in all vessels in the deposit area. The tissues at 2 to 10 minutes presented a faint pink appearance macroscopically (Fig. 5) with a wrinkling and shrinking of those in the deposit area. Haemolysis was

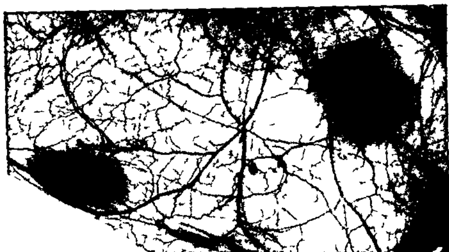


Fig 5 Cheek pouch of hamster 3 hours after application of Xylocain 2 (lower left) and Carbocain Thesat (upper right) Evans blue was administered to demonstrate increase in capillary permeability Leakage of plasma appears in the Xylocain area whereas the Carbocain Thesat is dominated by haemolysis and blocked circulation some leakage present in the marginal zone

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present in the whole area and high power magnification revealed more marked damage to the tissues The vessel walls were extensively destroyed with the content of the vessels escaping into the extravascular space

General disturbance of the microvascular structure included disintegration and disorganisation of almost all structural and cellular components intravascularly as well as in the extravascular space The microcirculation never recovered even partially A faint blue colour in the marginal zone indicating permeability disturbances (Fig 5) was noted Thrombus formation endothelial swelling microembolus formation and an increazed number of granulocytes adhering to the vessel wall were evident in this zone

Methylcellulose Gel (Bofors) caused the same disturbances in the microcirculation in the deposit area as described for Methylcellulose Gel (Astra) The times from the application of the solutions to the return of flow appear in Fig 2 No difference between these substances could be demonstrated no disturbance in the microvasular permeability was apparent

Perjodal and vehicles

Perjodal U The microcirculatory signs of tissue injury induced by Perjodal U after its application in the cheek pouch of the hamster were in accordance with the earlier reports by BRÅNEMARK et coll Deposition of the contrast medium produced increased transparency of the tissues in the area The time elapsing from the application to return of initial flow velocity appears in Fig 2 The microcirculation failed to return to normal in 2 out of 10 cases Segmental contractions in the arterioles were always present to a varying degree and white thrombi and in 3 cases even red thrombi were observed on the vessel walls granulocytes were sometimes evident on the endothelium The tissues of the 8 cases in which the microcirculatory flow returned to original values were stained intensely blue (Fig 3)

Perjodal S caused the same disturbances in microcirculatory structure and function as described for Perjodal U The general impression from the vital microscopic examination however was that Perjodal S was less toxic than Perjodal U The time from the application of the medium to the return of flow (Fig 2) and the degree of permeability disturbance (Fig 3) failed to confirm this impression at least in the limited number of experiments performed

The diodon dietanolamine solutions were extremely toxic to the tissues The flow in the microvessels after deposition immediately slowed down and after a few seconds to two minutes ceased entirely in all vessels in the deposit area The sequence of events was the same as after the application of other media namely

Discussion

The present investigation is one of a series on tissue injury caused by contrast media. The aim has been to elucidate the local tissue toxicity of different drugs (local anaesthetics and contrast media) used in diagnostic radiology of the urethra and bladder and the female genital organs.

Most investigations on local anaesthetics deal only with their analgesic properties (HAINES & GRABSTALD 1949, NESBITT & BAUM 1952, BOHN & KOLLGAARD 1959, LANGSTON et coll. 1967). In other reports the incidence of untoward local tissue reactions to application of urethral anaesthetics are described as negligible or absent or are not considered at all (NELSTEIN & HERMAN 1967, ROMANUS 1951). Some investigations have however dealt with the local toxic effects of anaesthetics (CORSSEN & ALLEN 1960, GREGG et coll. 1963, HARTSELL & STEPHEN 1965, WEIDLING 1948, TAIT et coll. 1958, MAYKUT 1958) and serious complications during the instillation of anaesthetics in the urethra after endoscopic procedures have even been described (WILLSON, PEPPER & ASHWI 1962).

The toxic effects of roentgen contrast media in urethrographic examinations have mainly been attributed to the occurrence of urethro-cavernous reflux and the local and systemic effects of this sequel (EDLING 1945, BENTZEN 1960, LINDBLOM & ROMANUS 1962, AAS 1965, VEIGA PIRES & ELEBUTE 1967).

The possibility that contrast media might have caused urethral *strictures* was investigated by EDLING, who however considered that *other factors* were more likely to have been responsible for the strictures that arose between two urethrographic examinations. VEIGA PIRES & ELEBUTE discussed the possibility that *contrast media* might cause thrombophlebitis, pyaemic emboli and subsequent small abscesses in the *corpora cavernosa*. The likelihood that contrast media and local anaesthetics instilled *in the urethra* may produce local tissue injury on contact with the *urethral tissue* appears not to have been *thoroughly* considered. Thus SCHUMANN 1967, LAPIDES & STONE 1968 *e.g.* failed to report any signs of local damage to the male urethra *after instillation* of contrast media. Nevertheless patients *often experience* serious symptoms after the roentgen examination performed as *described*: pain is often *experienced* even during instillation of the viscous anaesthetic into the *urethra although* the injection of the contrast medium usually elicits no *symptoms*. This is confirmed not only by experiments by the author but also by urologists and *surgeons* who examine *patients* at varying time periods after urethrocystography.

The examination procedure as *described* is carried out in direct continuation of double-contrast cystography and *implies that* the urethrography is performed immediately after instrumentation with a small catheter. This is not considered

first arrest in the small venules, secondly in the capillaries, later in the small arterioles and finally in the larger venules and arterioles The blood appeared coarse and *granular during the retardation of the flow velocity* *High resolution* microscopy disclosed severe deformation of all cellular elements in the vessels as well as in the extravascular space, the cell boundaries could often not be identified The vessel walls were severely damaged with loss of definition and endothelial lining and local destruction of the walls of the venules

The microcirculatory flow velocity never returned to original values Partial restitution in small circumscribed areas of the deposit region was evident but after five hours extensive areas without flow were still observed *Bleeding* into the tissues occurred in the areas with more or less recovery of flow as a consequence of the destruction of the vessel walls Severe segmental contractions (Fig 1 a) were present in the arterioles and venules with a great number of *granulocytes, white emboli* and *white* and *mixed thrombi*

Blue staining of the tissue could not be used as an objective measure of tissue toxicity as the physical prerequisite of perfusion pressure for diffusion of the protein bound Evans blue into the tissues did not exist An indication of the tissue toxicity of the two media examined by this test model could consequently not be obtained The vital microscopic investigations suggested however that, as could be expected the medium with the higher concentrations was the more toxic

The Dextran solutions caused disturbances in the microcirculation similar to those described after the application of Methylcellulose Gel solutions with immediate stasis in some microvessels Complete stasis was evident at two to five minutes in all venules except the largest as well as in the capillaries and smaller arterioles The time interval between application of the media into the tissue and restoration of microvascular flow velocities appears in Fig 2, from which it is evident that the solution with the highest viscosity caused the longest duration of microcirculatory arrest The transparency in the deposit area was increased and during the retardation in flow velocity the blood appeared coarse and granular The blood cells at complete cessation of flow were *deformed but* their boundaries could still be identified As a sign of tissue injury a great number of granulocytes were adhering to and sliding along the vessel walls The increase in the local microvascular granulocyte population was much greater after the application of Dextran than after Methylcellulose Gel A great number of pale thrombi adhered to the vessel walls and constituted an obstruction to the flow (Fig 1 a) The thrombi sometimes became detached from the vessel walls and passed through *the vessels as emboli*

The Dextran solutions never caused permeability disturbances recognizable with the technique employed

Discussion

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The examination procedure as described is carried out in direct continuation of double-contrast cystography and implies that the urethrography is performed immediately after instrumentation with a small catheter. This is not considered

a correct procedure (Morales & Romanus 1952, Lindblom & Romanus 1962). However, in a large roentgen department heavily loaded with routine examinations the desire for performing the whole urethrocystographic examination at one and the same time has to be *balanced against the possibility of complications.*

A comparison of the roentgen examination procedure with that of the urologist who first instils the local anaesthetic and then introduces an instrument indicates little practical difference in the possible injury applied. The radiologist adds a chemically and osmotically active substance to the anaesthetic medium while the urologist introduces a mechanical factor — a cystoscope or catheter. The essence of the matter is that more or less damaged tissue with consequently lowered threshold for injury comes in intimate contact with pharmacologically active substances. This is also the biologic situation in most of the cases in which urethrography is performed without preceding instrumentation.

It should be borne in mind that the patients referred for this roentgen examination *often have infected urine, cystitis or urethritis or a stricture with local* infection. From this it follows that the urethral mucous membrane is more or less damaged. This implies that anaesthetics as well as contrast media may add further injury to the already damaged tissue not only by direct action upon the mucosa but also by penetrating the submucous tissue and the corpus cavernosum as a result of rupture of the mucous membrane.

As local anaesthetics and contrast media under clinical conditions come into intimate contact with the tissues during urethrography the experimental model with tissue in the cheek pouch of the hamster as test site was considered suitable for elucidating the tissue toxicity of the drugs.

The phenomena of tissue injury were investigated by means of vital microscopy, *a method that has proved to be extremely sensitive and able to reveal even* slight disturbances in the microcirculation (Brånemark 1966, Brånemark et coll., Sørensen). It is also well suited for following the development of tissue reaction and the reversibility of injury. The vital microscopic examination was based on an investigation of the disturbances in microvascular flow, *different* degrees of wall adhesion of granulocytes and the formation of thrombi and microemboli. Segmental contractions of the vessels, the affection of the endothelium and the perivascular tissue were also investigated. The disturbances in microvascular permeability caused by the different solutions were examined by the technique earlier described by Sørensen.

The results presented make it obvious that all the drugs tested caused some injury to the tissues, the degree of which largely depended upon their nature.

A consideration of the results and a comparison of the two anaesthetics, Carbocain Thesit Gel and the Xylocain Gel, suggests the former being the more toxic to the tissues. Thesit is obviously the most toxic drug, this is a surface

tension lowering substance, presumably the reason it is added to a topical anaesthetic solution

Xylocain 2 % proved to be quite toxic and produced permeability disturbances as well as prolonged arrest in the microvascular flow On the other hand Carbocain 1 5 % caused no permeability disturbances and the alterations in microvascular flow were also less marked than after Xylocain No difference in tissue toxicity as revealed by the experimental test model was evident between the vehicle methylcellulose in the two commercial preparations

The investigation failed to disclose any definite difference between Perjodal S and U The general impression was gained however that Perjodal S was the less toxic of the two solutions as also was evident from the examination of the disturbance in flow and permeability (Figs 2 3) The reason for investigating two contrast media was that it was considered important from the results to explore the possibility of evaluating the influence of the concentration of the medium as well as of clarifying the significance of viscosity of Dextran in causing injury to the tissues

A consideration of the results after application of the diodone solutions (125 mg I/ml and 175 mg I/ml) indicated that both were so toxic that the test model employed was too sensitive to give an adequate impression of the degree of tissue injury A more exact comparison between the two solutions could therefore not be performed The reaction of the tissue in the cheek pouch of the hamster was severe with cellular disorganisation and destruction and total and permanent arrest of the microvascular flow The tissue toxicity of these substances should be determined by a less sensitive biologic test model The ear of the rabbit is considered to be suitable and an investigation of the damage caused by diodone solutions in this tissue is in progress

The toxicity of the Dextran solutions (viscosity 130 cSt and 400 cSt) proved to bear a direct relationship to the viscosity as appears from the investigation on disturbance of the flow velocities (Fig 2) the solution with the highest viscosity was the more toxic an important fact It is desirable that the fluid for urethrography is of high viscosity for optimal filling of and definition of the anatomy of the posterior urethra This requirement should however be weighed against the present findings that seem to indicate that the higher the viscosity the more toxic the substance to the tissue examined

Conclusion

The results indicate that the anaesthetic solutions (Carbocain Thesat Gel and Xylocain Gel) and the contrast media (Perjodal S and U) cause tissue injury to the cheek pouch of the hamster after local application An attempt has been made to determine which of the components of above mentioned

commercial drugs are mainly responsible for the local toxic effects of the preparations.

The salt is extremely toxic to tissues and the contrast medium in the Perjodal preparations (Diodon Dietanolamin solution 125 mg I/ml and 175 mg I/ml) was found to exert a marked local toxic effect.

Extrapolation of the findings from the laboratory to clinical work must be undertaken with caution. Animal experiments can at the best be indicative but not conclusive. It is perhaps surprising to find that Diodone, long ago abandoned because of its toxicity when injected intravascularly, is still used as contrast medium in preparations applied locally. It would appear logical for this seemingly out of date substance to be replaced by one of the more modern contrast media of the diatrizoate, metrizoate or iothalamate type. The results also seem to indicate that these should be dissolved in vehicles (such as solutions of Dextran) with as low viscosity as possible yet meeting the demands for the correct radiographic demonstration of the urethra.

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SUMMARY

The effects of roentgen contrast media and local anaesthetics generally used in the lower urinary tract and female genital system on microvascular structure and function were investigated in the hamster. The tissue toxicity of each of the components of the drugs was examined. All produced some change in the microcirculation and often extreme toxicity. The reversibility of the microvascular changes were examined and classified.

ZUSAMMENFASSUNG

Die Wirkungen von Röntgenkontrastmitteln und Lokalanästhetica, allgemein verwendet bei der Untersuchung der unteren Urinwege und des weiblichen Genitalsystems auf die mikrovaskuläre Struktur und Funktion wurden am Hamster untersucht. Die Gewebstoxicität jeder der Komponenten dieser Mittel wurden geprüft. Alle verursachten einige Veränderungen der Mikrozirkulation und vielmals eine extreme Toxicität. Die Rückbildbarkeit der mikrovaskulären Veränderungen wurde untersucht und klassifiziert.

RÉSUMÉ

L'auteur a étudié sur le hamster l'effet sur la structure microvasculaire et sur la fonction de moyens de contraste radiologique et d'anesthésiques locaux utilisés généralement pour les voies urinaires inférieures et l'appareil génital féminin. Il a étudié la toxicité tissulaire de chacun des composants de ces agents. Tous modifient la microcirculation et sont souvent extrêmement toxiques. L'auteur a examiné la réversibilité des modifications microvasculaires et les a classées.

REFERENCES

AAS T N Urethro-venös reflux (In Norwegian) Nord Med 73 (1965) 467

BARTLEY O and HELANDER C G Double-contrast cystography in tumors of the urinary bladder Acta radiol 54 (1960) 161

BENTZEN N Urethrographic studies of prostatic tuberculosis Thesis, Copenhagen 1960

BOHN C L S and KOLLGAARD J Xylocaingelanæstesi ved cystoskopi (In Danish) Ugeskr Læg 121 (1959) 168

BRANEMARK P I Intravital microscopy its present status and its potentialities Med biol Ill 16 (1966) 100

— and JONSSON J Determination of the velocity of corpuscles in blood capillaries A flying spot device Biorheol 1 (1963) 143

— JACOBSSON B and SORENSEN S E Microvascular effects of topically applied contrast media Acta radiol Diagnosis 8 (1969) 547

BREINE U Personal communication

CORSSEN G and ALLEN C R Cultured human respiratory epithelium its use in the comparison of the cytotoxic properties of local anesthetics Anesthesiology 21 (1960) 237

EDLING N P G Urethrocystography in the male with special regard to micturition Acta radiol (1945) Suppl No 58

GREGG J B BARNETT G L and ENSBERG D L Mucosal slough reaction to topical anesthetic Lidocaine Arch Otolaryng 77 (1963) 15

HAINES J S and GRABSTALD H Xylocaine a new topical anesthetic in urology J Urol 62 (1949) 901

HARTSELL C J and STEPHEN C R Incidence of sore throat following endotracheal intubation Surv Anesth 9 (1965) 458

KNUTSSON F On the technique of urethrography Acta radiol 10 (1929) 437

— Urethrography Acta radiol (1935) Suppl No 28

LANGSTO J B YEAGER P A SIMSELL W D and HORG M Evaluation of a topical anesthetic for us in urology Invest Urol 5 (1967) 149

LAPIDES J and STONE T E Usefulness of retrograde urethrography in diagnosing structures of the anterior urtehra J Urol 100 (1968) 747

LINDBLOM K and ROMANUS R Roentgen examination of the distal urinary tract of the male genital organs In Encyclopedia of Urology Vol 5 I Diagnostic Radiology ed by Alken C E Dix V Weyrauch H M and Wildbolz E Springer Verlag Berlin 1962

MAYKUT M O Studies on degeneration of myelin sheaths of nerves caused by long acting local anaesthetics injected subcutaneously into guinea pigs Canad J Biochem 36 (1958) 511

MORALES O and ROMANUS R Urethrography in the male with a highly viscous water-soluble contrast medium Umbradil — Viscous U Acta radiol (1952) Suppl No 95

NESBITT T E and BAUM W C Xylocaine Gel a new topical anesthetic agent Univ Mich med Bull 18 (1952) 157

NEUSTEIN D H and HERSMAN J R New urethral anesthetic Clinical evaluation employing new method N Y S J Med 67 (1967) 1401

NILSSON S Personal communication

ROMANUS R Anestesi av urethra med högviskost preparat (Xylocain Gel Astra) (In Swedish) Nord Med 45 (1951) 464

SCHUMANN E Die retrograde Urethrozystographie beim Manne und ihre Bedeutung für die

Röntgendiagnostik der extraperitonealen Organe des Beckens. Radiol. austr. 17 (1967), 255.

SORENSEN, S. E.: Changes in vascular permeability after local application of roentgen contrast media in the hamster cheek pouch. Acta radiol. Diagnosis 11 (1971), 274.

TAIT, C. A., REESE, N. O. and DAVIS, D. A.: A comparative study of Hexylcaine, Procaine and Lidocaine with specific attention to tissue irritation. Sth. med. J. 51 (1959), 358.

WEIDLING, S.: The locally irritating effect of metal ions and local anaesthetics. Acta pharmacol. 4 (1948), 351.

VEIGA PIRES, J. A. and ELEBUTE, E. A.: Urethrocystography in the male. Brit. J. Urol. 39 (1967), 194.

—— Radiology of the male urethra. Ann. Radiol. 10 (1967), 5.

WILLSON PEPPER, J. K. and ASHWIN, R. I.: The permeability of the urethral mucosa. Brit. J. Urol. 34 (1962), 51.

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FOURTH VENTRICLE

II Tumours of the cerebellum

by

MARIO CORRALES and TORGNY GREITZ

The progress of modern neurosurgical techniques including various stereotaxic methods has increased the need for a more accurate localization of posterior fossa lesions. Even with conventional surgical methods the earlier classification of e.g. cerebellar tumours in upper and lower vermis or hemispheric tumours (LYSHOLM 1939, LINDGREN 1954, TAVERAS & WOOD 1964, HILAL et coll. 1969) has not always been sufficient; this is particularly true when the tumour is not immediately recognized at the exploration of the posterior fossa. It is also of importance to know whether a cerebellar tumour involves the brain stem and makes radical removal impossible. The displacement and deformity of the fourth ventricle are usually of decisive importance in indicating any extension of posterior fossa tumours. The diagnostic accuracy has been increased by a combined anatomic and radiologic investigation of the appearances of the fourth ventricle with various lesions in the posterior fossa. The normal anatomy of the fourth ventricle was described in part I of the present investigation (CORRALES & GREITZ 1972). This communication will deal with tumours of the cerebellum but will not include intraventricular neoplasms. These tumours as well as intra- and extra-axial neoplasms will be considered in a later publication.

From the Department of Neuroradiology (Director: Prof. T. Greitz), Karolinska Sjukhuset, Stockholm, Sweden. Submitted for publication 3 December 1970.

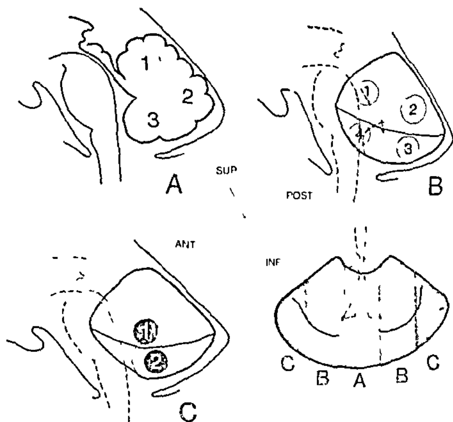


Fig. 1 Main directions and classification to define tumour locations. The cerebellum is divided into five sagittal sections: one median (A) and two lateral on each side (B and C)

Directions. All locations and displacements were oriented in relation to the sagittal plane in the following directions. Anteriorly or perpendicular to the clivus, posteriorly or in the opposite direction towards the tentorium, and, at right angles with these directions superiorly towards the tentorial notch and inferiorly towards the foramen magnum and the occipital bone (Fig 1)

Locations. The tumour locations were classified in the following way in order to define as exactly as possible the site of a posterior fossa lesion. The cerebellar growths were divided into vermis and hemispheric neoplasms, intraventricular tumours in the fourth ventricle being excluded. The vermis neoplasms consisted of three groups (Fig. 1). The first group includes superior vermis growths located superior to the fastigium and the superior posterior fissure (position A 1), i.e. tumours in the central lobulus and in the culmen. Position A 2 is at the level of the fastigium and includes the declive, the folium and the tuber. Position A 3 lies inferior and anterior to the tuber and includes the pyramid, the uvula and the nodulus. Growths in these three positions may be termed superior,

posterior and inferior vermis tumours respectively The hemispheric neoplasms have been classified as medial (position B) and lateral (position C) Because the hemisphere reaches more anteriorly and superiorly than the vermis section B has been divided into four quadrants by two dividing lines one parallel to the horizontal fissure and the other at right angles to it The superior anterior quadrant is called B 1 the superior posterior B 2, the inferior posterior B 3 and the inferior anterior B 4 The location of tumours in the B 4 position lies close to the pontine angle Due to the shape of the posterior fossa and the hemisphere section C is considerably smaller and is divided into only two parts one upper or C 1 and one lower or C 2

Materials and Methods

Experimentally produced balloon tumours Tumours in the posterior fossa especially those in the cerebellum are usually not exclusively restricted to one section but involve neighbouring areas and are usually fairly large An experimental investigation was carried out on the displacement and deformation caused by expanding lesions strictly limited to one area in 18 cadavers of mostly elderly subjects without previous suggestion of neurologic disease A Fowler balloon catheter was introduced through the occipital bone below the transverse sinus and brought into position under roentgen control Through another burr hole in the parasagittal frontal region a cannula was placed in the third ventricle and central ventriculography (AZAMBUJA et coll 1956) performed with a water soluble contrast medium (Methylglucamine Conray) that was allowed to run down into the aqueduct the fourth ventricle and the cisterna magna (Fig 2) It was usually possible to avoid filling the basal cisterns The quantity injected varied from 20 to 40 ml or just enough to secure good filling of the fourth ventricle Lateral and a p half axial films having been obtained the balloon was inflated with air until it reached a diameter of about 2 5 cm Further films in the same projections were then taken and the displacements and deformities noted

Additional air was usually injected in order further to expand the balloon and another radiologic check of the accompanying changes was made The balloon was then deflated until it was almost empty and the anatomic changes were observed Following this sometimes after slight reinflation of the balloon the cerebellum and the brain stem were carefully removed in one piece together with the balloon and immediately fixed in formalin for at least two months The specimens were carefully dissected and examined in the same way as the tumour material following a scheme that aimed at revealing changes in all the anatomic details pertinent in this connection These included the floor and the

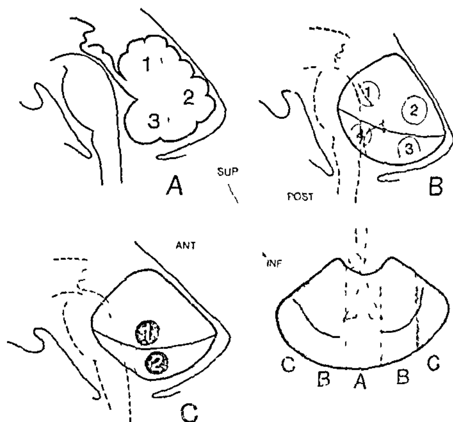


Fig. 1. Main directions and classification to define tumour locations. The cerebellum is divided into five sagittal sections: one median (A) and two lateral on each side (B and C).

Directions. All locations and displacements were oriented in relation to the sagittal plane in the following directions: Anteriorly or perpendicular to the clivus, posteriorly or in the opposite direction towards the tentorium, and, at right angles with these directions superiorly towards the tentorial notch and inferiorly towards the foramen magnum and the occipital bone (Fig. 1).

Locations. The tumour locations were classified in the following way in order to define as exactly as possible the site of a posterior fossa lesion. The cerebellar growths were divided into vermis and hemispheric neoplasms, intraventricular tumours in the fourth ventricle being excluded. The vermis neoplasms consisted of three groups (Fig. 1). The first group includes superior vermis growths located superior to the fastigium and the superior posterior fissure (position A 1), i.e. tumours in the central lobulus and in the culmen. Position A 2 is at the level of the fastigium and includes the declive, the folium and the tuber. Position A 3 lies inferior and anterior to the tuber and includes the pyramid, the uvula and the nodulus. Growths in these three positions may be termed superior,

Table 1

Aut psy material Site and pa hologic dia nosis of tumours listed in table 4

Tum ur number	Ma n site of tumour	Pathology
1	A 2	Tentorial meni gi na haemorrhag
2	A 3	Not specified
3	A 3	Medullobl stoma
4	A 3	Ependym ma
5	B 1	Men ngioma
6	B 2	Ast ocytoma
7	B 2	Angioret culoma
8	B 3	Angioreticuloma
9	B 4	Medulloblastoma
10	B 4	Haemorrhage
11	C 2	Metastases

di ectioning and ectioning was carefully performed as in the experimental material

Radiologic investigation of clinical material A total of 758 ca es with po terior fo a tumours was examined by encephalography or ventriculography during the period 1945—70 Three hundred and eighty two (382) or 66 per cent out of the 588 cases examined at Serafimerlasarettet and 150 or 88 per cent of tho e een at Karolinska Sjukhuset had air filling of the fourth ventricle Tumours growing mainly intraventricularly as well as intra and extra axial neoplasms will be discussed in later publications and were therefore omitted After this primary election there remained 177 cerebellar tumours which were subjected to a econdary selection according to the following principles First only tho e ca es were selected in which an adequate examination both in lateral and p a projections had been made to allow an evaluation of the anatomic details of the fourth ventricle Ca es were then chosen in which a atis factory idea of the site of the le ion could be obtained from the operation report and in which the tumours eemed to be confined only or at least mostly to one area as defined above After this econdary selection there remained 74 cases (Table 2 which had been examined with ventriculography and after 1950 with ventriculography as well as with encephalography Twenty of the e cases were examined at Karolinska Sjukhuset. The technique of encephalography was mainly by the method described by LINDGREN (1949) in later years with modifications made possible by the construction of suitable tomographic equipment (GREITZ & GREPE 1967 FREDZELL et coll 1968) Tomography with a

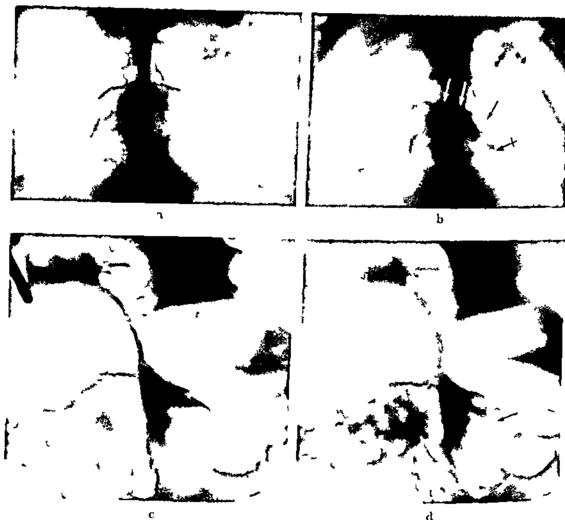


Fig 2 Experimental material Central ventriculography with water soluble contrast medium performed in a case with the balloon in the B 2 position a) c) Before insufflation b) d) Lateral and anterior displacement of the fourth ventricle The ipsilateral posterior superior recess (⟶) is displaced anteriorly medially and inferiorly and is compressed the contralateral recess being shifted laterally and also compressed The fastigium (white arrows) is tilted anteriorly on the balloon side The ipsilateral lateral recess (⟷) is displaced anteriorly and medially

fastigium, the superior posterior and lateral recesses of the fourth ventricle, the anterior medullary velum the central lobulus and the nodulus

Anatomic investigation of tumour material About 20 museum specimens of the cerebellum and the brain stem with posterior fossa tumours were examined This material included 11 tumours in the cerebellum or adjacent structures (Table 1) The changes produced by neoplasms in the B 4 position were compared with those caused by extracerebellar pontine angle tumours All these specimens had been fixed by freely floating in formalin to prevent distortion The



Fig 3 Autopsy mater al a) c) E perimental balloo t tumour (B) in B 2 po it on b) Astrocytoma a d d) ang ret culoma both in B 2 posit on (T) a) b) S ctions at the level of the posterior supe r r e sses w th anterior and medial d splacement and compression of the ps lateral recess (⟶) c) d) Sect ons at the level of the lateral recess s wh ch are displaced med ally and anter orly on th ffe t d s de (⟷) and l terally on the cont alat ral side with concom tant flatten ng of the ndentat on t the l el of the dent te nucleus (⟷) The shape of th rest form body (▶) is diff nt on the two sides ts curve is flattened on the affected side and accentuated on the contra late l de The s m larity betwe n the changes produced by the expe imental balloon tumour and those c ed by the neopl sms is obv ous

tumours located inferiorly or in the A 3 B 4 and C 2 positions there was upward movement No upward nor downward change was evident when the balloon tumour was located at the same level as the fourth ventricle in the superior inferior directions i e in the A 2 B 2 and C 1 positions As regards lateral displacement the upper part of the fourth ventricle was more displaced than the lower part with the balloon in the B 1 position the opposite occurred in the B 3 B 4 and C 2 positions (With the B 3 position the vallecula was more displaced than the inferior part of the fourth ventricle) No difference between the upper and lower part existed with other lateral growths The displacement

Table 2

Clinical material Distribution of tumours according to their main sites following the classification in fig. 1

Main site	A1	A2	A3	B1	B2	B3	B4	C1	C2	Total
Number of cases	6	8	5	7	13	20	4	5	6	74

linear tomograph, Mimer II, was applied in all the 20 cases mentioned and was found to be of considerable value. All cases were carefully scrutinized with regard to the above mentioned anatomic details.

Results

Experimental investigations. The balloons caused deformities and displacements similar to those occurring in the pathologic specimens as well as in pneumographs in vivo (Figs. 2, 3, 4, 12, Table 3). However, the tumours so produced were smaller than those usually evident during life and no surrounding oedema existed, the changes were thus more subtle, as an example the typical kink of the aqueduct never being marked. Due to the fact that all changes could be checked radiologically against the conditions that existed before the insufflation of the balloon, even minor alterations could be evaluated with a high degree of accuracy.

The general displacements of the fourth ventricle in posterior fossa tumours, such as its forward movement with cerebellar neoplasms, are well known and have been listed for the sake of completeness (Table 3). Apart from these changes, small alterations to the several minor structures occurred. As these latter changes have not been adequately or completely described earlier and as they seem to be of great localizing value they were given special and thorough attention.

Balloon tumours located in the cerebellum produced significant anterior displacement in most locations except for the B 1, B 4 and C 1 positions, in which only a slight or almost no anterior movement was evident when the balloon was within the cerebellar hemisphere (Fig. 5, Table 3), with the balloon situated outside the cerebellum in the B 4 position, that is close to the pontine angle, backward displacement was apparent. The C 2 position of the balloon produced a definite forward shift as against the C 1 position due to the fact that the fourth ventricle is not parallel to the clivus, its inferior part being more anterior. With the balloon situated superiorly, as in the A 1 and B 1 positions, downward displacement of the fourth ventricle was evident and with

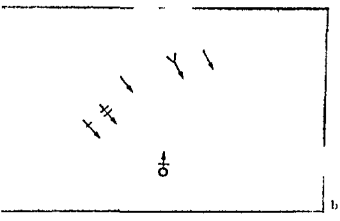
Table 3

Displacements and deformities produced in the balloon experiments in fig 3. The majority of these observations were made both at ventriculography and in specimens. The classification of tumour sites is according to fig 1. X = present, 0 = absent or absence of changes + = increased — = decreased. Parenthesized symbols indicate subtle changes

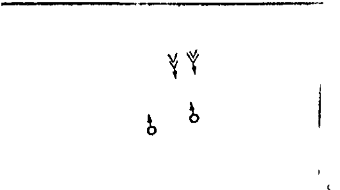
Balloon tumour number	1	2	3	4	5	6	7	8	9
Site	A1	A2	A3	B1	B2	B3	B4	C1	C2
Fourth ventricle									
General displacement	ant inf	ant	ant sup	(ant) inf lat	ant lat	ant lat	(ant) lat (sup)	lat (ant	ant lat up
Height	—	—	—	0	—	—	0	—	—
Floor width	0	0	0	—	0	0	—	—	—
Floor tilt	0	0	0	x	x	x	x	0	0
Velum									
Displacement	ant inf	ant	sup (ant)	ant lat inf	ant lat	lat	lat	lat	lat
Tilt	0	0	0	x	x	(x)	x	0	0
Width	—	0	—	—	(—)	0	0—	—	—
Curv frontal	—	—	—	—	0	(+	0 —)	—	0—
Curv lateral	—	—	(—	—	—	0	—	—	0—*
Fastigium									
Displacement	ant inf	ant	sup ant	(inf lat	ant lat (inf)	ant lat	sup lat	lat sup	lat sup
Compression	x	x	x	x	x	x	(x)	(	(x
Nodulus									
Displacement	inf	ant	sup ant	inf lat	ant (lat) (inf)	ant lat	lat	lat (sup)	lat
Compression	x	(x)	x	(x)	(x)	(x)	(x)	x	(x)
Support recess									
Ipsilateral									
Displacement	ant inf less than fastigium	ant	sup	med inf	med inf ant	med ant	med post	med	med
Compression	x	x	x	x	x	x	x	x	(x)



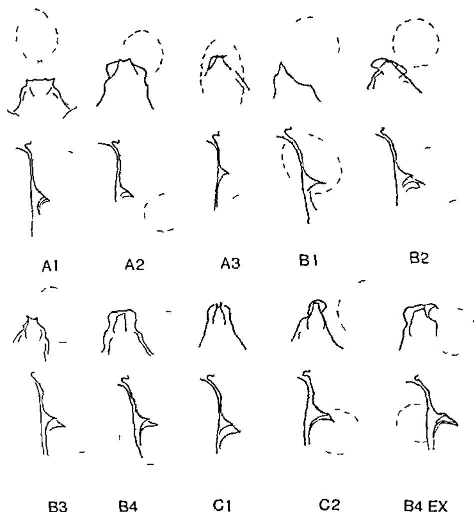
a



b


c

g 4 Clinical materi il I ncephalography in metast isis in the B 2 position Deformities the same in the experimental m it ri il (figs 2 3) Posterior sup ri r recesses (—→) Lateral recesses (↦) dentation of dentate nucleus (⟷) fastigium (≻→) velum ( ) floor ( ) and obex (⤚→) The ape of the lower part of the br in stem is identical to that in (c) and (d) (The composite drawing the a p projections summ ri z s the findings in several cuts in the following illustrations only e most relevant cut appears)



F g 5 Displacements and deform t e in the balloon expe iments Tumour locations accord ng to f g 1 Dotted line i d cates po ition of fourth vent icle before and continuous l ne after nsuffla t n of b lloon Interrupted l n represents balloon

position produced posterior movement of the floor on the affected side (Fig 5) with all other locations no tilt of the floor was apparent A tilted floor was always accompanied by a tilt of the anterior medullary velum in the same direction with one exception the B 4 position, in which the velum was tilted in the opposite direction this change in the velum was most marked in the B 1

Table 3 *(cont.)*

Balloon tumour number	1	2	3	4	5	6	7	8	9
Site	A1	A2	A3	B1	B2	B3	B4	C1	C2
Contralateral									
Displacement	ant inf less than fastigium	ant	sup	lat	(lat)	(lat)	0	(lat)	0
Compression	x	0	x	0	0	(x)	(x)	(x)	(x)
Lateral recess									
Ipsilateral									
Displacement	ant	ant	ant	med ant inf	med ant	med ant	med ant	med ant	med ant
Compression	0	0	0	x	x	x	x	x	x
Contralateral									
Displacement	ant	ant	ant	lat	lat	lat	lat	lat	(lat)
Compression	0	0	0	0	0	0	0	0	0

* with large balloon

with B 4 intracerebellar and with C 1 tumours was however most marked in the middle part with a concomitant indentation from the lateral aspect in the wall of the fourth ventricle.

Table 3 also lists changes in position of minor structures adjacent to the fourth ventricle. These displacements were compared with the general displacement of the fourth ventricle in an attempt to evaluate whether the alteration in position of a local structure is more marked than that of the remainder of the fourth ventricle. The nodulus is, for example, pushed upwards to a greater extent than the remainder of the walls of the fourth ventricle with a balloon in the A 3 position. The central lobulus was moved laterally when the upper part of the fourth ventricle was more displaced than its lower part. Similarly, the roof of the fourth ventricle, i.e. the velum, could be displaced more laterally than the floor (Figs. 2, 12).

In addition to the above changes rotation of the fourth ventricle was also observed, i.e. one side was rotated more anteriorly or posteriorly than the other. Such a change occurred with the balloon tumours in the B 1, B 2 and B 3 positions (Table 3, Fig. 5), the floor being pushed forward on the tumour side. Extracerebellar B 4 location of the balloon, as opposed to an intracerebellar

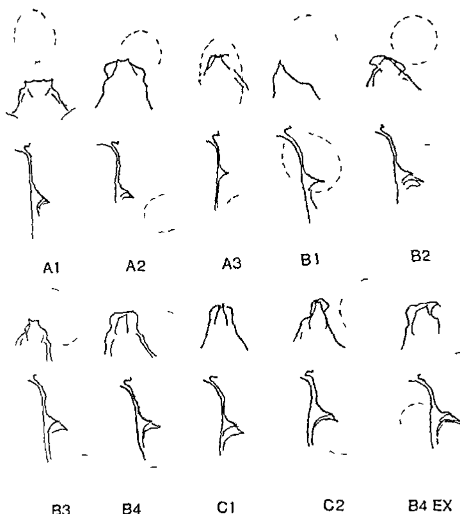


Fig Displacements and deformation in the balloon experiments Tumour locations according to fig 1 Dotted line indicates position of fourth ventricle before and continuous line after insufflation of balloon Interrupted line represents balloon

position produced posterior movement of the floor on the affected side (Fig 5) with all other locations no tilt of the floor was apparent A tilted floor was always accompanied by a tilt of the anterior medullary velum in the same direction with one exception the B 4 position in which the velum was tilted in the opposite direction this change in the velum was most marked in the B 1

Table 3 *(cont.)*

Balloon tumour number	1	2	3	4	5	6	7	8	9
Site	A1	A2	A3	B1	B2	B3	B4	C1	C2
Contralateral									
Displacement	ant inf less than *fastigium*	ant	sup	lat	(lat)	(lat)	0	(lat)	0
Compression	x	0	x	0	0	(x)	(x)	(x)	(x)
Lateral recess									
Ipsilateral									
Displacement	ant	ant	ant	med ant *inf*	med ant	med ant	med ant	med ant	med ant
Compression	0	0	0	x	x	x	x	x	x
Contralateral									
Displacement	ant	ant	ant	*lat*	lat	*lat*	lat	lat	*(lat)*
Compression	0	0	0	0	0	0	0	0	0

* with large balloon

with B 4 intracerebellar and with C 1 tumours was however most marked in the middle part with a concomitant indentation from the lateral aspect in the wall of the fourth ventricle.

Table 3 also lists changes in position of minor structures adjacent to the fourth ventricle. These displacements were compared with the general displacement of the fourth ventricle in an attempt to evaluate whether the alteration in position of a local structure is more marked than that of the remainder of the fourth ventricle. The nodulus is, for example, pushed upwards to a greater extent than the remainder of the walls of the fourth ventricle with a balloon in the A 3 position. The central lobulus was moved laterally when the upper part of the fourth ventricle was more displaced than its lower part. Similarly, the roof of the fourth ventricle, i.e. the velum, could be displaced more laterally than the floor (Figs 2, 12).

In addition to the above changes rotation of the fourth ventricle was also observed, i.e. one side was rotated more anteriorly or posteriorly than the other. Such a change occurred with the balloon tumours in the B 1, B 2 and B 3 positions (Table 3, Fig. 5), the floor being pushed forward on the tumour side. Extracerebellar B 4 location of the balloon, as opposed to an intracerebellar

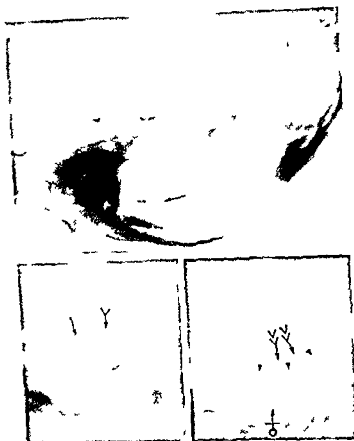


Fig 7 Cl n al mater al Spcn oblast ma in A 1 pos t n with B 2 compcn nt Th fa t gium (>→) i duplac d anter r nfe i ly t) th level of the ps late al poster r superior r cesses (—→ Th velum (»→ is br aden d and indent d by th tum ur (▶ The nfe ior pa t with the r bex (—→) as r pposed to the narkedly compres ed uperi r part is well outlin d

di placement of the nodulus the upper pole of which indents the inferior a pect of the fourth ventricle and by compressing the fastigium cau es a decrease in its height Fig 10 This phenomenon might be explained by the medial di placement of the tonsil compres ing and pu hing the nodulus superiorly A imilar mechani m may explain the upward di placement of the fastigium observed with the B 4 position although no ignificant decrea e in the height of the fourth ventricle was apparent The decreased height in the remainder of ca es was con i tent with an anterior movement of the fastigium Apart from

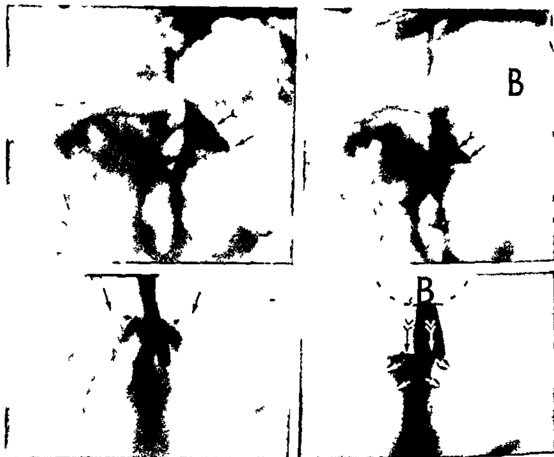


Fig. 6. Experimental ventriculography with balloon (B) in A 1 position. Air in fourth ventricle delineates its floor. The fourth ventricle as well as the fastigium (→) and the posterior superior recesses (⟶) are displaced anteriorly and inferiorly, the fastigium more than the latter which are markedly compressed. The velum (»→) is displaced in the same directions and broadened. The superior part of the fourth ventricle is more compressed than the inferior part and less evident in the a.p. projection, which outlines only the inferior part (white unlabelled arrows).

and B 2 positions. Balloon tumours located lateral to and at about the same level as the fourth ventricle were often associated with a diminution in the width of the floor of the fourth ventricle; this sometimes occurred with the B 4 and with the C 1 and C 2 positions. This lateral compression of the fourth ventricle was probably causing the increase in the height in the C 2 position, the only position in which an experimental cerebellar tumour caused increased height as measured to the fastigium; otherwise it was decreased and, excepting in the C 1 position for obvious reasons. The height as measured to the posterior superior recess on the tumour side was increased with growths in the B 4, C 1 and C 2 positions. With the C 1 position, the decrease in height seemed to be caused by the upward

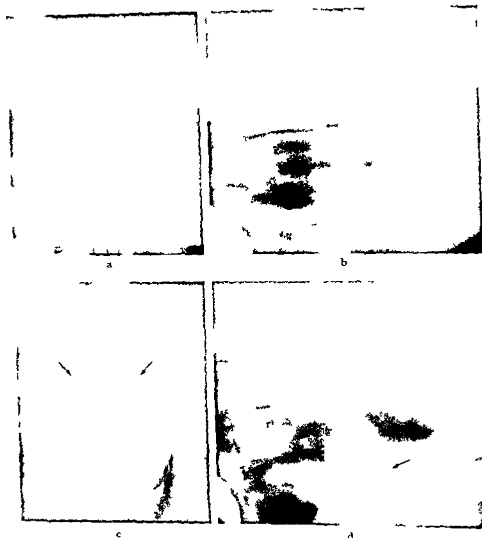


Fig 9 Clinical material Angioreticuloma in the A P position The decreased height and the compression of the posterior superior recesses (—→) before operation (a and b) become apparent on comparison with the pistope at [illegible] findings six weeks later (c and d) of no atrophy of the cerebellum no hydrocephalus

The superior posterior recesses may be displaced and compressed from their anterior posterior lateral or superior aspects When there was marked compression of these recesses any filling disappeared completely in the balloon experiments Upward displacement was produced by the tonsil compressing from



Fig. 8. Autopsy material. Intracerebellar haemorrhage following the removal of a meningioma of tentorium in the A 2 position with additional A 1, A 3 and B 2 components. The fourth ventricle is displaced anteriorly and compressed from behind resulting in a decrease in its height. The velum (»→) is broadened due to the A 1 component and compression against the brain stem; its tilt is caused by the B 2 component.

the two locations mentioned, i.e. the C 1 and B 4 positions, the fastigium was pushed upwards also with the A 3 and C 2 (Fig. 5) positions and downwards with the A 1 and B 1 positions (Fig. 7). These changes were due either to an upward displacement of the nodulus or a downward movement of the central lobulus, which affected the size and shape of the anterior medullary velum. The upward displacement of the posterior part of the fourth ventricle, i.e. the nodulus, and the fastigium, resulted in an increased curve of the central lobulus and velum not only in the lateral but frequently in the frontal plane as well (Fig. 5). The latter deformity could also be explained by lateral compression due to the fact that the space available for the structures superior to the fastigium decreased as they were pushed up against the tentorial notch and became squeezed in the funnel formed by the tentorium, petrous bones, and the clivus. This may also explain why narrowing of the anterior medullary velum occurred with tumours in the lower vermis (A 3 position). Narrowing of the velum and, at the same time, an increase in its curve in the p.a. projection was recorded in the B 1, B 4, C 1 and C 2 positions due to compression from the lateral aspect of the neoplasm (Fig. 5). Broadening of the velum and a straightening of the normal impression of the central lobulus in the a.p. projection was evident with A 1 tumours and was most likely due to direct compression by the mass and resulted in a flattening of the central lobulus (Fig. 5). Cerebellar neoplasms posterior to the fastigium displaced the nodulus anteriorly, thus compressing the channel of Magendie.

Table 4 (*cont.*)

Tumour number	1	2	3	4	5	6	7	8	9	10	11
Main site	A2	A3	A3	A3	B1	P2 (M)	B?	B3	B4	B4	C2
Additional component	A3 B1 B?	B3 left	bil B3 A2	(brain stem)	B4	B3	B3	B?	0	0	0
Contralateral											
Displacement	ant	(sup)	ant (sup)	lat	(lat)	lat	lat	lat	(lat)	lat	lat
Compression	x	(x)	x	x	0	0	x	0	0	x	(x)
Lateral recess											
Ipsilateral											
Displacement	ant	(ant)	(ant)	ant	med ant	med ant	med ant	med ant	med ant	med ant	med ant
Compression	0	0	0	0	x	x	x	x	x	x	x
Contralateral											
Displacement	ant	(ant)	(ant)	ant	lat	lat	lat	lat	lat	lat	lat
Compression	0	0	0	0	(x)	(x)	(x)	0	x	(x)	(x)

below, other displacements were always produced by the displacement of adjacent cerebellar tissues such as the dentate nucleus (Fig. 3 a). The superior posterior recesses were usually moved in the same direction as the fastigium, i.e. inferiorly with superior tumours and superiorly with inferior tumours. When the growth was situated laterally, the displacement of the recess was frequently more marked than that of the fastigium. It was thus pushed downwards to a greater extent than the fastigium in B 1 tumours and more posteriorly than the fastigium with the balloon in the pontine angle position. There was one exception to this rule. Backward displacement of the recess without concomitant backward change in position of the fastigium occurred with B 4 intracerebellar tumours. The movement of the superior posterior recesses in midline tumours could be less marked than that of the fastigium. This happened with the balloon in the upper part of the vermis (A 1); the displacement and compression of the recess was sometimes marked in comparison with the changes in the neighbouring structures. As an example, with the B 2 position the recess was almost completely compressed and the anterior and inferior movement was greater than that of the fastigium (Figs. 2, 3, 5). The tilt of the fastigium was thus more marked than that of the velum, but the most obvious change was the lateral displacement of the velum exceeding that of the floor (Figs. 2, 5).

Table 4

Displacements and deformities observed in specimens with tumours listed in table 1. Classification and symbols as in table 3. The symbol (—) when used with regard to the height of the fourth ventricle denotes decrease due to obliteration of the fastigium by compression

Tumour number	1	2	3	4	5	6	7	8	9	10	11
Main site	A2	A3	A3	A3	B1	B2	B2	B3	B4	B4	C[illegible]
Additional component	A3 A1 B2	B3 left	bil B3 A2	(brain stem)	B4	(A1) B3	B3	B[illegible]	0	0	0
Fourth ventricle											
General displacement	ant (sup)	ant sup (lat.)	ant sup	ant sup	(ant) lat	ant lat	ant lat	ant lat	lat	lat	lat
Height	—	—	—	—	0	—	—	—	0	0	0
Floor width	0	0	0	0	—	+	+	+	—	—	—
Floor tilt	0	0	0	0	x	x	x	x	x	x	0
Velum											
Displacement	ant	sup	sup	sup	lat	lat ant	lat ant	lat	lat	lat	lat
Tilt	x	0	0	0	x	x	x	(x)	x	x	0
Width	+	0	0	0	—	(+)	—	0	0	—	—
Curve frontal	—	0	+	0	(+)	—	(+)	(+)	0	+	+
Curve lateral	—	+	+	+	0	+	(−)	+	0	+	+
Fastigium											
Displacement	ant	ant	sup	sup	lat	lat ant	lat ant	lat	lat	lat	lat
Compression	0	0	x	x	x	x	x	x	0	0	x
Nodulus											
Displacement	ant	sup	sup	sup	lat	lat ant	lat ant	lat ant	lat	lat	lat
Compression	0	0	0	enlarged invaded	x	x	x	x	0	0	x
Sup post. recess											
Ipsilateral											
Displacement	ant	ant sup	ant (sup)	lat sup	inf post	ant inf	ant inf	ant (sup)	med post	med post	med
Compression	x	x	x	x	x	x	x	x	x	x	x

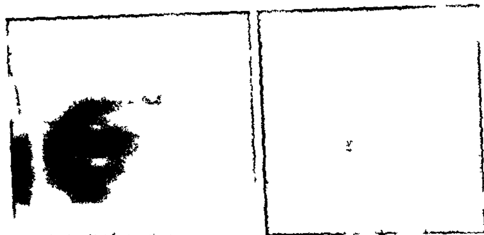


Fig 11 Clinical material Angioreticuloma in A 3 position with B 3 components Marked superior and anterior displacement of the fourth ventricle with compression of the posterior superior recesses and fastigium resulting in decreased height The velum is slightly tilted (B 3 component) The fourth ventricle is narrow

occupied a larger area than the balloon Due to this fact the deformities and displacements in this material were as a rule more complex and more marked and at the same time less specific than in the material of experimentally provoked tumours Nevertheless strikingly similar deformities could be observed in growths in corresponding positions in the two materials (Fig 3) Certain observations were more difficult to make by inspection of the specimens than by the roentgen investigation of the experimental growths Changes in the position of the fourth ventricle supero-inferiorly were especially difficult to evaluate On the other hand certain deformities such as a broadening or a tilt of the roof or the floor of the fourth ventricle were more easy to determine in specimens

The observations are listed in Table 4 and indicate that no tumour was evident with its centre or main bulk in the A 1 and C 1 positions The tumour in the A 2 position was extremely large and had a component corresponding to the A 1 location which explains the flattening and broadening of the velum (Fig 8 b) The curve of the central lobulus was also straightened out in the lateral projection probably due to compression by the large mass against the brain stem (Fig 8 a) The tilt of the velum observed was due to a significant B 2 component

There were three tumours in the A 3 position one with an unilateral B 3 component (Fig 10 d) another with a bilateral B 3 component and a third with a small component in the upper part of the medulla (Fig 10 b c) They all presented the same changes with regard to the fourth ventricle but some dif

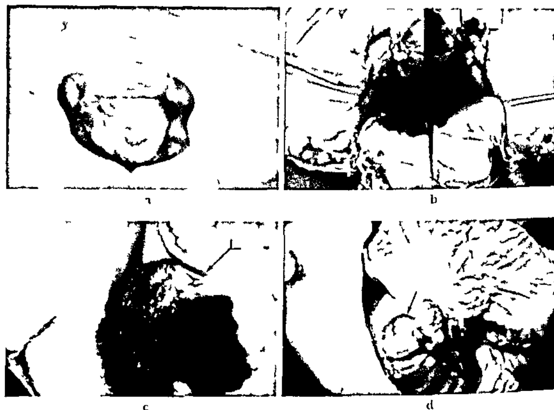


Fig. 10 Autopsy material a) Experimental tumour in A 3 position causing upward displacement of nodulus which protrudes between the tonsils b) c) Ependymoma in the A 3 position causing protrusion of the nodulus which is also responsible for the obliteration of the fastigium (>→) as in (c) This latter change explains the decreased height of the fourth ventricle at ventriculography with tumours in this position d) Medulloblastoma in the A 3 position with marked anterior and upward displacement of the fourth ventricle This cut slightly lateral to the midline depicts the groove (→) of the less superiorly displaced upper pole of the tonsil in the lateral surface of the nodulus The double contour of the velum suggests an increased curve in the frontal plane

The lateral recess of the fourth ventricle was always moved anteriorly with compression of the brain stem This movement was bilateral in midline growths and unilateral in lateral tumours In lateral lesions the compression from behind also resulted in straightening or medially directed curving of the ipsilateral recess and lateral displacement of the contralateral recess The medial change in position of the ipsilateral recess in most hemispheric tumours was most prominent in the posterior part of the recess, as opposed to the findings with the extracerebellar B 4 position, which resulted in the medial displacement being more marked in the anterior part of the recess

Pathologic material As stated above most of the tumours in the autopsy material were not confined to one specific location Only 3, one in the C 2 and two in the B 4 position, among the 11 tumours of the cerebellar hemisphere failed to involve an adjacent area, furthermore, the neoplasms generally



Fig 13 Cl n cal material Metastasis in the B 1 pos tion The ro f of the fourth ventr cle includ ng the velum (»—›) i tilted and the ip lateral po te ior super or recess (—›) markedly compre sed and d placed antero infer orly w th the ipsilateral brach um conj nctivum (»→) The body of the f urth ventricle is rep esented as an area of dec ea ed absorpt on between the rece ses and is ob i u ly compressed ts r ght border is poorly d fined probably because it is t lted away from the beam as in fig 12 a The super or part of the fourth ventricle and the adjace it part of the aqueduct are d placed laterally and n the lateral view ndent d from beh nd The marked d splacement and def m ty of the e structu es as well as the compres ion of the body and the less prominent anter or di placement of th fourth ent icle d stinguishes tumou s in the B 1 f om tho e in the B 2 pos tion

the fourth ventricle and the deformation of the adjacent structures were in accordance with tho e pre ent in the balloon specimen with two exceptions which could both be explained as being due to the B 4 component These con isted in an absence of any movement downwards of the fourth ventricle marked narrowing of its floor and elevation on the tumour side of the velum which was displaced more posteriorly in its anterior than its posterior aspect finally, there was no accentuation of its curve in the lateral projection The height of the fourth ventricle was not decreased anatomically but again it was lowered by compression from above and obliteration of the fastigium As in the balloon case (Fig 12 a) the ipsilateral superior posterior recess was displaced inferiorly on the tumour side and more than the fastigium which displayed no definite evidence of movement inferiorly The lateral recesses presented changes that were identical to those ob erved in the fixed specimen with the balloon tumour The ipsilateral recess (Fig 12 c) was displaced medially and anteriorly, particularly in its posterior part it was al o pushed downwards The posterior part of the contralateral recess was shifted laterally

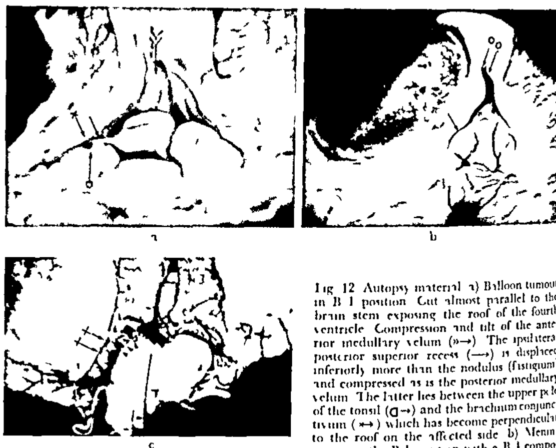


Fig 12 Autopsy material a) Balloon tumour in B 1 position Cut almost parallel to the brain stem exposing the roof of the fourth ventricle Compression and tilt of the anterior medullary velum (»→) The ipsilateral posterior superior recess (—→) is displaced inferiorly more than the nodulus (fastigium) and compressed as is the posterior medullary velum The latter lies between the upper pole of the tonsil (ɑ→) and the brachium conjunctivum (↣) which has become perpendicular to the roof on the affected side b) Meningioma in the B 1 position with a B 4 component Similar cut as in (a) but viewed from the posterior aspect to reveal compression of the floor (o→) caused by the B 4 component The displacements and deformities of the posterior superior recess (—→) and adjacent structures are similar to those in the balloon experiment (a) c) Same tumour as in (b) Marked medial displacement of the ipsilateral lateral recess (↔) chiefly posteriorly and lateral displacement of the contralateral recess with concomitant deformation of the upper medulla and the restiform bodies (▶)

ferences were observed in relation to the superior posterior recesses In the case with the unilateral B 3 component the upward displacement of the superior posterior recesses was more marked on the side of this component Compared with the changes with the balloon in the A 3 position, the only difference was greater accentuation of the curve of the central lobulus in the lateral projection This might have been due to an increase in the upward displacement of the fastigium and the nodulus in the tumour specimens As in the balloon experiment no decrease in the height of the fourth ventricle was evident anatomically but the height of the cavity was reduced by obliteration of the fastigium caused by its compression by the upward movement of the nodulus (Fig 10 c)

One growth in the B 1 position, a meningioma of the tentorium (Fig 12 b, c), was included in the material, this had a significant B 4 component The shift of



Fig 15 Clinical material Cystic astrocytoma in the B 3 position Marked anterior displacement of the fourth ventricle the height of which is decreased only a slight tilt of the body but no narrowing No filling of the ipsilateral posterior or superior recess possibly due to obliteration The main difference from the changes caused by a B 2 tumour is the absence of inferior displacement of the fourth ventricle and of the ipsilateral posterior or superior recess which may be obliterated Further more the kink of the aqueduct is more prominent in relation to the size of the tumour

was a small tumour and the changes were at variance with the experimental tumour with regard to the width of the floor which appeared wider than normal There were two tumours in the B 4 position one a medulloblastoma (Fig 16 a) and the other a meningioma with a well circumscribed postoperative haematoma lying entirely within the cerebellum (Fig 16 b c d) Both these lesions were of a purer B 4 location without any component in the adjacent areas including the pons and with deformity of the fourth ventricle that was almost identical to that in the balloon experiment (Fig 5) This deformity consisted in compression of the ventricle laterally causing decreased width of the floor and roof As in the balloon experiment there was a tilt of the velum which was displaced posteriorly on the tumour side (Fig 16 a b) The specimen with the postoperative haematoma had like the balloon specimen a reversed tilt of the floor i e anteriorly on the affected side (Fig 16 c) Only a slight tilt of the floor was evident in the medulloblastoma The difference from this standpoint might probably have been due to the haematoma being larger and most likely also explains the narrowing and concomitant increased curvature of the velum (Fig 16 b) changes that could also be provoked by a large balloon in the same position Changes in the lateral recess were the same as those in the above tumours in B positions but differed from those in extra axial B 4 tumours

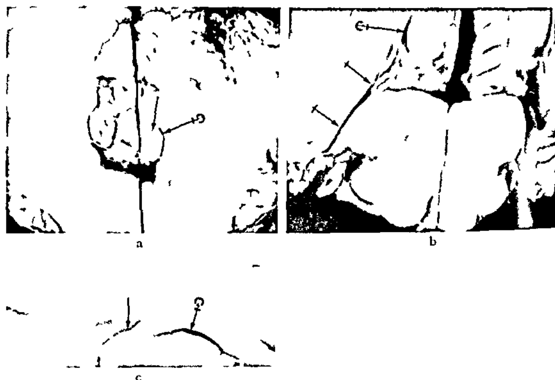


Fig 14 Autopsy material Angioreticuloma in the B 3 position with slight B 2 component a) Horizontal cut inferior to the fastigium through the upper pole at the tonsils The fourth ventricle and the tonsil are displaced anteriorly on the tumour side The recess (—→) is partially obliterated (b and c) Obliteration also of the posterolateral fissure (c→) best seen in (b) The lateral recess (→→) on the affected side is compressed and displaced medially mostly in its posterior part the contralateral recess is moved laterally deformity of the restiform bodies also present

There were two tumours in the B 2 position (Fig 3 b d), one with a marked B 3 and a slight A 1 component, the other, which was larger, had a slight B 3 component Upward herniation as well as downward herniation were present in both instances In the case with the large B 3 component these herniations were unilateral and in the other they were bilateral Broadening of the velum, probably due to the A 1 component, was evident in the first case and narrowing of the velum as seen in the balloon experiment occurred in the other case Accentuation of its curve in the frontal plane probably due to the considerable size of the mass which had also caused lateral compression was also observed This might also have explained the flattening of the curve of the velum in the sagittal plane in the latter as being due to compression against the brain stem The deformities of the superior posterior and lateral recesses were in both cases entirely in accordance with the observations in the balloon experiments This was also true in regard to the tumour with its main bulk in the B 3 position, a cystic angioreticuloma (Fig 14), which had a significant B 2 component This



Fig 15 Clinical material Cystic astrocytoma in the B 3 position Marked anterior displacement of the fourth ventricle the height of which is decreased only a slight tilt of the body but no narrowing No filling of the ipsilateral posterior superior recess possibly due to obliteration The main difference from the changes caused by a B 2 tumour is the absence of inferior displacement of the fourth ventricle and of the ipsilateral posterior superior recess which may be obliterated Further more the kink of the aqueduct is more prominent in relation to the size of the tumour

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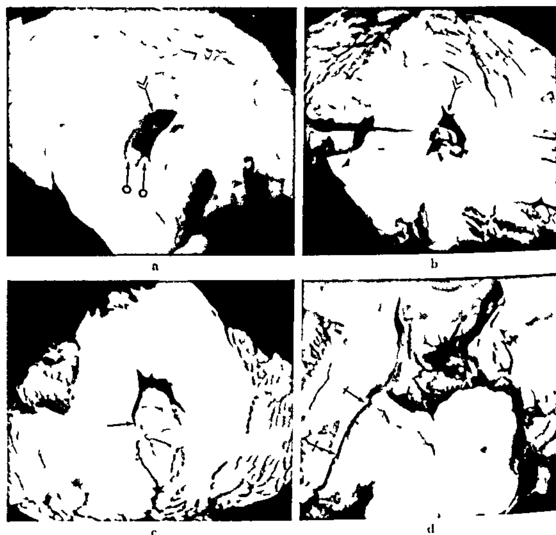


Fig. 16. Autopsy material. a) Medulloblastoma in B 4 position. Compression from the lateral aspect of the fourth ventricle including its floor ( ) which is tilted slightly anteriorly on the involved side. The velum (»→) is tilted in the opposite direction. b) c) Intracerebellar haemorrhage in the B 4 position following operation for meningioma. The compression of the fourth ventricle is less obvious than in the previous case. Tilt of the velum (»→) posteriorly on the affected side. c) d) The posterior superior recess (—→) as well as the ipsilateral lateral recess (+→) is compressed laterally. The former is also pushed posteriorly (—→).

Clinical material. An attempt was made to classify the clinical material by the same locations as in the experimental and the pathologic material. The result of this classification is presented in Table 2. The operation reports indicate that the neoplasm frequently occupied not only one area as listed in this table but adjacent structures as well. Although only those cases in which a satisfactory idea of the site of the tumour could be obtained from the reports were selected, the exact limits of the tumour could not be assessed. It was therefore not possible to carry

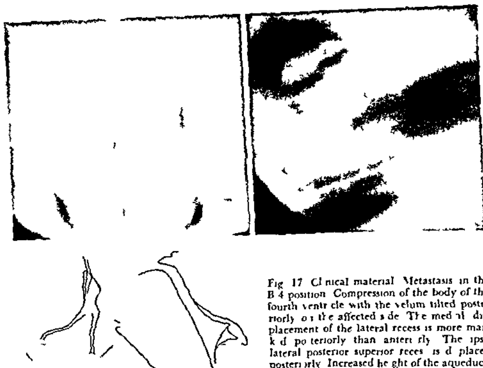


Fig 17 Clinical material Metastasis in the B 4 position Compression of the body of the fourth ventricle with the velum tilted posteriorly on the affected side The medial displacement of the lateral recess is more marked posteriorly than anteriorly The ipsilateral posterior superior recess is displaced posteriorly Increased height of the aqueduct

out a detailed analysis as in the pathologic material Good agreement between the deformities observed and the location indicated by the surgeon usually occurred With one or two exceptions a representative growth could be found for each location i e a tumour that from the operation report did not extend beyond a specific area (A 1 A 2 etc) These growths appeared to cause almost the identical deformities as occurred in the balloon experiments and the displacements and deformities in these cases may therefore be considered to be typical for the specific location

The results have to a great extent confirmed earlier observations on the change in position of the fourth ventricle in posterior fossa tumours Observations of certain anatomic details such as the width of the floor and roof of the fourth ventricle as well as the movement and compression of its superior posterior and lateral recesses would appear to increase the diagnostic accuracy in all tumours of the posterior fossa

As to general displacements of the fourth ventricle it is wellknown that neoplasms of the posterior compartment such as vermis tumours push it forwards and those of the anterior compartment e g the pontine tumours, press it back

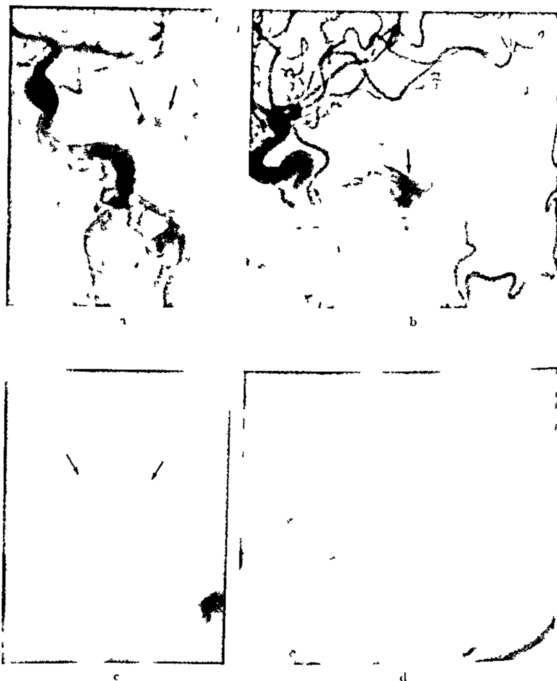


Fig 18 Clinical material Metastasis from adenocarcinoma (a, b) Angiography Vascular growth supplied by meningeal branches strictly confined to the C L position (c) d) Encephalography in the same case The fourth ventricle is both displaced and compressed laterally The posterior superior recess (⟶) is displaced slightly posteriorly on the contralateral side but not on the ipsilateral side a fact that distinguishes a neoplasm in this location from one in the B L or in the pontine angle position



Fig 19 a) Experimental material Balloon in C 2 position produces lateral compression and local indentation in the body (→) and in the posterior superior (→) and lateral (→) recesses b) Autopsy material The same compression on local deformity of the posterior superior recess as in (a) is present (→) The nodulus is compressed

wards Our results indicate that growths lying anteriorly in the cerebellar hemisphere as in the B 1 B 4 and C 1 positions, cause less forward shift Posterior displacement of the fourth ventricle was never produced in the material by a tumour of the cerebellum Intracerebellar neoplasms close to the pontine angle in contrast to the extracerebellar growths thus failed to push the fourth ventricle backwards The most marked lateral movement of the body occurs in inferior tumour and is most prominent in lateral lesions as those in the C 1 and C 2 positions (Figs 18 19 20) The aqueduct and the upper part of the fourth ventricle are more altered in position than the lower part of the latter in growths located superiorly (B 1) (Fig 1)

Evaluation of a movement of the fourth ventricle as a whole in a supero-inferior direction is also of value mainly in assessing the boundaries of tumours close to the median line Marked upward displacement occurs only in tumours of the lower vermis and downward shift only in growths of the upper vermis or in those with an upper vermis component (Figs 4 7) Tumours may be in a high position as in B 1 or B 2 positions without causing any marked downward displacement as well as in low (B 3 B 4 C 1 and C 2) positions without causing any noticeable upward movement The supero-posterior recesses may however often be clearly displaced anteriorly or posteriorly (Fig 17)

The observation of such relative displacements is obviously important Hence *in midline tumours* the positions of median structures such as the central lobulus and the nodulus are relatively more altered in the *sagittal plane than* the more lateral structures like the tonsils The relationship in more lateral tumours may be reversed An example of this is the marked inferior displacement of the

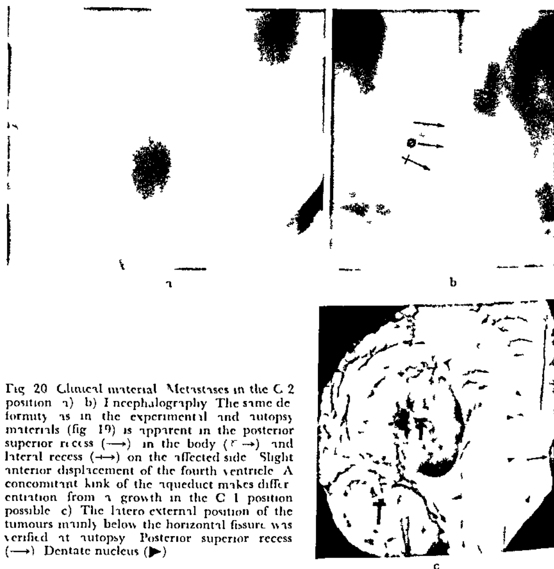


Fig 20 Clinical material Metastases in the C 2 position a) b) Encephalography The same deformity as in the experimental and autopsy materials (fig 19) is apparent in the posterior superior recess (—→) in the body (⊢→) and lateral recess (+→) on the affected side Slight anterior displacement of the fourth ventricle A concomitant kink of the aqueduct makes differentiation from a growth in the C 1 position possible c) The latero external position of the tumours mainly below the horizontal fissure was verified at autopsy Posterior superior recess (—→) Dentate nucleus (▶)

fastigium relative to the supero posterior recesses in the A 1 positions (Fig 7) as against the more marked shift of the recess compared to that of the fastigium in the B 1 position (Fig 13 b) The nodulus was pushed up in relation to the tonsils in growths located inferiorly Such an upward movement of the nodulus by pressure from below and behind was probably responsible for the fact that the height of the fourth ventricle was diminished in such cases This change produced compression of the fastigium which decreased the height of the air filled cavity of the fourth ventricle (Fig 11), although this height might not anatomically have been diminished A true decrease in the height of the fourth ventricle was caused by growths of the mid part of the vermis, which produced anterior displacement and compression from behind of the fastigium

and the superior posterior recesses (Fig 9 b) No decrease was evident (Figs 18 c 20 a) in lateral tumours in the C 1, C 2 and B 4 positions even a possible increase in height could sometimes be observed (Fig 17)

Flattening and broadening of the velum in the a p projection was present in upper vermis tumours (Fig 7 c) This curve was increased in some growths of the lower vermis (Figs 10 d 11 b) with possibly a decreased width of the velum (Fig 11 b) An accentuation of the curve of the velum in the a p projection may also be caused by lateral compression This change may be produced by any lateral mass and was observed with growths in the B 1, B 2 B 4 and C 2 positions (Table 4, Figs 16 b 17)

The anterior medullary velum may also be tilted This arises from posterior compression in postero lateral tumours like those in the B 1, B 2 and B 3 locations and the tilt may be greater above than below with the tumour in a superior position (B 1) A tilt produced by anterior compression occurred with neoplasms in the B 4 position (Figs 16 a b, 17)

Increased width of the floor was evident in those tumours of the cerebellum that caused hydrocephalus as well as in those that compressed the brain stem posteriorly as occurred with some A 1 and B 2 tumours (Figs 4 b 7 b) Decreased width of the floor was recorded in growths lying laterally in the hemisphere as in the B 4 C 1 and C 2 positions (Figs 16 17) Those in the B 4 location compressed mainly the floor those in the B 1 chiefly the velum, and those growths in the C 1 and C 2 positions both equally

Acknowledgements

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SUMMARY

Changes in the fourth ventricle with special reference to minor anatomic details have been investigated at autopsy and in a clinical material of cerebellar tumours The alterations were compared with those arising in some experimentally provoked balloon tumours The value of tomography in the encephalographic examination of these growths is emphasized

ZUSAMMENFASSUNG

Veranderungen im vierten Ventrikel besonders im Hinblick auf feinere anatomische Details sind in einem autoptischen und klinischen Material von Cerebellartumoren unter

sucht worden. Die Veränderungen werden mit solchen verglichen, die bei einigen experimentell hervorgerufenen Ballon-Tumoren auftreten. Der Wert der Tomographie bei der encephalographischen Untersuchung dieser Gewächse wird hervorgehoben.

RÉSUMÉ

Les auteurs ont étudié par autopsie et sur des cas cliniques de tumeurs cérébelleuses les modifications du quatrième ventricule en s'intéressant particulièrement à des détails anatomiques mineurs. Ces modifications ont été comparées avec celles qui apparaissent dans certaines tumeurs simulées expérimentalement par des ballonnets. Les auteurs soulignent l'intérêt de la tomographie dans l'examen encéphalographique de ces tumeurs.

REFERENCES

AZAMBUJA, N., ARANA INIGUEZ, R., SANDE, M. T. and GARCIA GUELFI, A.: Central ventriculography. Acta neurol. latinoam. 2 (1956), 58.

CORRALES, M. and GREITZ, T.: Fourth ventricle. I. A morphologic and radiologic investigation of the normal anatomy. Acta radiol. Diagnosis 12 (1972), 113.

FIELDZELI, G., GREITZ, T., GREPE, A. and HOLMSTRÖM, L.: Mimer III and rotating chair. Acta radiol. Diagnosis 7 (1968), 543.

GREITZ, T. and GREPE, A.: Mimer II and rotating chair. Application in neuroradiology. Elema Schönander, Stockholm 1967.

HILAL, S. K., TOOKOIAN, H. and WOOD, E. H.: Displacement of the aqueduct of Sylvius by posterior fossa tumors. Acta radiol. Diagnosis 9 (1969), 167.

LINDGREN, E.: Some aspects on the technique of encephalography. Acta radiol. 31 (1949), 161.

— Handbuch der Neurochirurgie, Band II. Springer Verlag, Berlin 1954.

LYSHOLM, E.: Ventriculography of the fourth ventricle. Amer. J. Roentgenol. 41 (1939), 18.

TAVERAS, J. and WOOD, E.: Diagnostic neuroradiology. Williams and Wilkins, Baltimore 1964.

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LESIONS OF THE BLOOD BRAIN BARRIER FOLLOWING SELECTIVE INJECTION OF CONTRAST MEDIA INTO THE VERTEBRAL ARTERY IN RABBITS

Comparison between lesions of brain and spinal cord

by

P G JEPPSSON and T OLIN

Selective angiography of the spinal cord has been increasingly used during the last few years (BAKER et coll 1967 DJINDJIAN et coll 1969 DI CHIRO et coll 1970) It has been suggested that the spinal cord may be more vulnerable to roentgen contrast media than the brain

The neurotoxicity of such media has been investigated by their injection into the internal carotid artery (for references see JEPPSSON & OLIN 1970) Neurotoxicity MARGOLIS et coll 1956 1958 TORNELL 1968 KILLEN et coll 1959 1960) has also been investigated in lesions of the spinal cord following injection into the aorta HOL & SKJERVEN (1959) examined the damage to the blood brain barrier with a trypan blue technique in the prone and supine positions at aortography No direct comparison of the vulnerability of the brain and the spinal cord to roentgen contrast media has however been made The neurotoxicity of such media following their injection into the vertebral artery was investigated by determination of the smallest amount needed to provoke general

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Fig. 1. Anomaly of the left vertebral artery (→→). A common trunk (→) with the superficial cervical artery arising directly from the aortic arch. Selective catheterization not possible.

seizures (OLIN & REDMAN 1967). The damage to the blood brain barrier was then demonstrated by trypan blue in one of the rabbits. Lesions were revealed in the spinal cord, the brain stem and the cerebellum. The injection of contrast media into the vertebral artery thus makes it possible simultaneously to investigate the vulnerability of the blood brain barrier in the brain and spinal cord. This was the purpose of the present investigation.

Material and Methods. General anaesthesia was obtained with intravenous Pentobarbithalum INN (mebumalnatrium), in about 60 rabbits. The blood pressure was measured from a catheter in the left femoral artery and the left vertebral artery catheterized from the right femoral artery (OLIN & REDMAN 1967). The position of the catheter was controlled by the injection of Thorotrast. The injection of the iodated contrast media was performed at a constant rate (0.16 ml/s) with an infusion machine, the filling of the basilar artery was followed by magnification fluoroscopy. The time during which the basilar artery was filled was called the application time and recorded with a stop-watch. Blood pressure and the duration of the injection were recorded on a polygraph and the rectal temperature was measured. The blood brain barrier was investigated as

described by JEPPSSON (1962), the cervical cord was however also included. In the case of a variation in the degree of injury of the blood brain barrier the most damaged area was taken as representative of the actual structure if it extended over at least half of the damaged region in the brain or the spinal cord. The doses of contrast medium applied were 5.0, 2.5 and 1.25 ml to 3 animals respectively, at each dose level. The following contrast media were investigated: Isopaque Cerebral (metrizoate meglumine 59.1 % Ca 1.13 %), Urografin 60 % (diatrizoate meglumine 52 % Na 8 %), Angiografin 65 % (diatrizoate meglumine 65 %), Conray Meglumin (iothalamate meglumine 60 %).

Results

About a third of the animals were excluded due to the following reasons: in a pilot investigation a dose of 10 ml contrast medium killed five animals before the trypan blue investigation could be completed; this dose was therefore abandoned. Selective catheterization was unsuccessfull in twelve animals due to various complications such as spasm and vascular anomalies. The vertebral artery sometimes arose as a common trunk with the superficial cervical artery, selective catheterization of the true vertebral artery being unsuccessful. The vertebral artery or the common trunk mentioned sometimes arose directly from the aortic arch proximal to the subclavian artery (Fig. 1), so that selective catheterization was impossible.

Urografin 60 % (Table 1) damages the blood brain barrier of the brain and the spinal cord in doses of 5.0 and 2.5 ml. Some lesions of the brain even occur with 1.25 ml of the contrast medium. The concentration of the contrast medium in the basilar artery sometimes fluctuated with the pulse. General seizures occurred with 5.0 and 2.5 ml doses. Lesions of the blood brain barrier often appeared in animals that had reacted with such seizures, bradycardia and an elevated blood pressure.

Angiografin 65 % (Table 2) caused lesions of the blood brain barrier of the brain and the spinal cord at 5.0 and 2.5 ml doses; only minimal injuries to the brain occurred at the 1.25 ml dose level. Pulsations were sometimes observed in the basilar artery at fluoroscopy; general seizures occurred with 5.0 ml and once with 2.5 ml of contrast medium. Circulatory effects such as bradycardia and elevation of blood pressure were often evident in conjunction with seizures and blood brain barrier lesions.

Conray Meglumin 60 % (Table 3) also caused damage to the blood brain barrier at 5.0 and 2.5 ml but with the 1.25 ml dose only minimal lesions were present in one brain. The brain and the spinal cord were damaged to the same



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Table 1 *(cont.)*

Blood pressure			Degree of injury	
Before	During		Brain	Spinal cord
	Highest	Lowest		
1[illegible]0/85	155/110	155/110	++	(+)
160/80	190/135	170/70	++	+(+)
150/90	210/110	210/110	++	+(+)
125/90	150/105	125/85	neg	neg
110/75	140/100	140/100	++	+
90/70	140/115	140/115	+++	+++
80/70	70/65	70/65	+	(+)
95/70	135/106	80/60	++(+)	(+)
85/60	85/55	80/55	neg	neg

Table 2 *(cont.)*

Blood pressure			Degree of injury	
Before	During		Brain	Spinal cord
	Highest	Lowest		
75/60	120/75	70/50	+++	++
39/25	45/25	45/25	+	(+)
115/75	135/90	125/65	+++	+++
115/80	[illegible]/110	[illegible]/70	+(+)	+(+)
110/75	[illegible]/90	[illegible]/90	++(+)	++(+)
8[illegible]/65	95/70	60/45	(+)	neg
70/50	80/55	65/45	neg	neg
95/65	110/80	110/80	(+)	neg
110/80	130/90	105/70	(+)	neg

Result common to the different series The application time in the basilar artery with a given dose was of the same magnitude for the different contrast media and was proportional to the volume injected

Table 1

Results with Urografin 60 %

Rabbit	Contrast medium (vol. ml)	Body wt (kg)	Body temp at inj (°C)	Inj time (s)	Application time (s)	Convulsions	Pulse/min Before	Pulse/min During
A 19	5.0	1.7	37.5	32.0	29.8		360	270
A 20	5.0	2.6	39.9	32.0	25.0	+	330	120
A 23	5.0	2.8	39.0	31.5	30.0	+	300	90
A 24	2.5	1.8	37.0	17.6	17.1		270	270
A 25	2.5	2.7	39.5	17.2	16.1	+	360	240
A 29	2.5	2.6	39.0	16.4	18.5	+	330	270
A 30	1.25	2.4	38.0	8.8	9.5		300	300
A 31	1.25	2.4	39.0	—	7.6		330	300
A 34	1.25	2.1	38.0	10.0	10.0		270	240

Table 2

Results with Angiografin 65 %

Rabbit	Contrast medium (vol. ml)	Body wt (kg)	Body temp at inj (°C)	Inj time (s)	Application time (s)	Convulsions	Pulse/min Before	Pulse/min During
A 35	5.0	2.1	37.0	—	31.1	+	270	120
A 36	5.0	2.0	37.5	31.6	29.8	+	300	210
A 37	5.0	2.3	37.5	32.0	32.6	+	270	120
A 45	2.5	3.1	38.0	—	16.0	+	360	210
A 46	2.5	2.4	37.0	17.2	15.8		300	270
A 48	2.5	1.9	37.0	17.2	16.5		270	270
A 54	1.25	1.9	36.5	8.8	8.2		240	210
A 55	1.25	2.0	37.0	10.8	9.0		360	210
A 56	1.25	1.8	37.0	8.2	8.2		240	150

degree, seizures never occurred. Only minimal pulsations were evident in t[he] basilar artery at fluoroscopy.

Isopaque Cerebral 60 % (Table 4) produced minor damage to the bloo[d] brain barrier in 5.0 and 2.5 ml doses. No seizures were noticed. Pulsations we[re]

Table 1 *(cont)*

Blood pressure			Degree of injury	
Befor	During		Brain	Spinal cord
	Highest	Lowest		
130 85	155/110	1 5,110	++	(−)
160 80	190 135	1 0 70	++	−(+)
150 90	210 110	210/110	++	−(−)
175 90	150 105	175/85	neg	neg
110 75	140 100	140/100	++	−
90 70	140/115	140/115	+++	+++
80 70	70 65	70 65	+	(−)
95/70	135 10f	80 60	++(+)	(−)
85 60	85/55	80 55	n g	neg

Table 2 *(cont)*

Blood pressure			Degree of injury	
B fore	During		Bra n	Spinal cord
	H ghest	Lowest		
75 60	120/75	70 50	+++	++
39 25	45 25	45 25	+	(+)
115 75	135/90	125 65	+++	+++
115 80	/110	/70	+(+)	+(+)
110/75	/90	/90	++(−)	++(+)
85 65	95/70	60 45	(+)	neg
70 50	80 55	65 45	neg	neg
95 65	110 80	110 80	(−)	neg
110 80	130 90	105/70	(+)	neg

Result common to the different series The application time in the basilar artery with a given dose was of the same magnitude for the different contrast media and was proportional to the volume injected

Table 3

Results with Conray Meglumin 60 %

Rabbit	Contrast medium (vol ml)	Body wt (kg)	Body temp at inj (C)	Inj time (s)	Application time (s)	Pulse/min Before	Pulse/min During
A 61	5 0	1 7	36 5	33 0	32 0	270	180
A 62	5 0	1 7	38 5	32 5	31 4	270	180
A 63	5 0	2 3	37 5	—	32 0	—	—
A 58	2 5	1 8	37 5	17 6	17 0	180	150
A 59	2 5	2 7	36 5	17 8	16 6	270	270
A 60	2 5	1 7	39 5	18 0	16 5	270	180
A 65	1 25	1 5	39 0	12 0	11 9	300	180
A 66	1 25	1 7	37 8	9 4	10 2	300	300
A 67	1 25	2 7	—	9 0	6 0	270	270

Table 4

Results with Isopaque Cerebral 60 %

Rabbit	Contrast medium (vol ml)	Body wt (kg)	Body temp at inj (C)	Inj time (s)	Application time (s)	Pulse/min Before	Pulse/min During
A 6	5 0	1 7	38 0	32 0	30 8	330	180
A 8	5 0	1 8	37 0	32 4	30 4	270	150
A 9	5 0		37 5	31 4	32 1	300	210
A 12	2 5	1 5	37 5	18 0	17 5	330	300
A 15	2 5	2 3	37 5	14 6	11 5	300	300
A 17	2 5	2 2	38 0	17 6	17 1	300	300
A 69	1 25	2 9	36 5	8 6	8 8	–	—
A 71	1 25	3 1	37 5	9 3	8 6	240	210
A 72	1 25	2 2	39 5	8 9	7 5	330	330

The spinal cord was damaged no more than the brain in any of these series (Fig 2) The lesions were more marked on the left side (the site of injection) and appeared on the right side of the brain only with high doses The damaged

Table 3 *(cont)*

Blood pressure			Degree of injury	
Before	During		Brain	Spinal cord
	Highest	Lowest		
60/45	115,90	60/45	++	+(+)
105 80	120 95	90 70	++	++
—	—	—	+(+)	+(+)
95 65	130 95	130 95	+	+
75 60	100 65	100 65	neg	neg
90 65	105/70	105/70	++	+ +
70 50	110 85	110 85	neg	neg
75/60	85/70	86/70	neg	neg
110 90	115,95	100/75	+	neg

Table 4 *(cont)*

Blood pressure			Degree of injury	
Before	During		Brain	Spinal cord
	Highest	Lowest		
120 85	140,85	140/85	(+)	(+)
145 90	160 90	130/70	+	neg
115/100	115/95	95/85	(+)	neg
110 85	115 85	70/55	+	neg
110/90	130/100	110/80	+(+)	+
120 90	140,90	140/110	neg	neg
—	—	—	neg	neg
100 80	100/80	90/75	neg	neg
130 105	165/130	130,95	neg	neg

area was as a rule confined to the upper third of the cervical cord So called in
verse lesions on the side contralateral to the injection never occurred in the spinal
cord The lesions in the lower brain stem and the cerebellum were mostly located

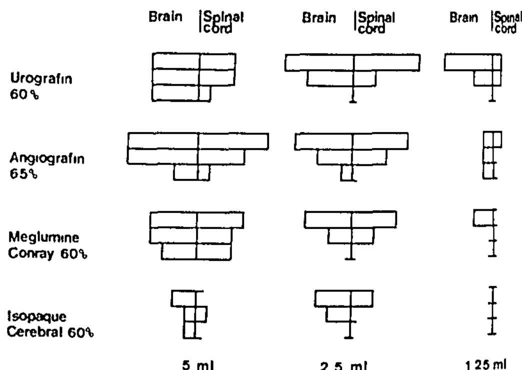


Fig. 2. Survey of the degree of injury to the blood brain barrier in the different experimental series.

on the same side as the injection. Lesions higher up in the brain stem or in the cerebral hemispheres were sometimes somewhat more obvious on the contralateral side. Microscopic examination of the brain and the spinal cord revealed that the barrier lesions were most marked in the grey substance, even in the spinal cord.

A comparison of the different series indicates that the diatrizoate compounds (Urografin 60 % and Angiografin 65 %) caused similar lesions to the blood brain barrier and produced seizures in 5.0 and 2.5 ml doses. Conray Meglumin and Isopaque Cerebral never caused seizures in the doses administered. Conray Meglumin led to lesions of the blood brain barrier to nearly the same extent as the diatrizoate compounds. Isopaque Cerebral seems to give rise to less obvious lesions to the blood brain barrier but even this contrast medium was not completely atoxic in 2.5 ml doses.

Discussion

Catheterization of the vertebral artery proved to be a difficult procedure and was unsuccessful in twelve cases. A catheter with its tip moulded to a rather open, S shape again proved to be most suitable (OLIN & REDMAN 1967). Anatomic

anomalies sometimes made selective catheterization difficult or hindered it completely as mentioned The distribution of the vertebral artery in the rabbit has been mapped by GOUAZE et coll (1963) it supplies the upper part of the cervical part of the spinal cord the brain stem and the cerebellum The lesions of the blood brain barrier evident in the spinal cord secondary to injection into the vertebral artery have all been localized to its upper cervical part A previous investigation (KILLEN et coll 1959) revealed that Thorotrast does not damage the blood brain barrier No injury was caused to the blood brain barrier in the present material with only a small dose of iodated contrast medium following the Thorotrast Good agreement between the injection time the volume injected and the application time was reached in the examination of the toxicity of contrast media injected into the internal carotid artery There was also good agreement between the injected volume and the application time The pial vessels on the surface of the cerebellum were observed through a burr hole in a pilot investigation Injection into the vertebral artery and fluoroscopy disclosed that in spite of filling of the basilar artery no expulsion of blood from the pial vessels occurred Such expulsion was however obtained by forceful manual injection It was therefore decided to take the time during which the basilar artery was filled with contrast medium as the application time The concentration of the contrast medium in the basilar artery sometimes fluctuated due to dilution with blood from the other vertebral artery This might have been due to a change in vascular tone evoked by the contrast medium interference with the general circulation or spasm in the vertebral artery around the tip of the catheter It was thus impossible to maintain the criterion of complete expulsion of blood from the basilar artery Pulsation in the concentration of the contrast medium in the basilar artery occurred in 15 of the animals, this was observed during the whole injection period in four animals but for only short periods in the remainder No relation to the changes in the general circulation was evident The only notable coincidence was that with 2 5 ml doses of Iopaque Cerebral all animals had pulsations in the basilar artery and small or no lesions of the blood brain barrier No correlations between the pulsations in the basilar artery the dose and the lesions were otherwise apparent

The investigations have indicated that Urografin 60 % produces a rise in blood pressure bradycardia and seizures in conjunction with the lesions of the blood brain barrier bradycardia however, is not present as often as increases in the blood pressure with lesions of the barrier Angiografin 65 % has less effect on the general circulation Both diatrizoate compounds evoked general seizures in 5 0 and 2 5 ml doses Conray Meglumin 60 % however failed to produce seizures although bradycardia occurred at high dose levels also combined with lesions to the blood brain barrier The blood pressure rose as a rule on injection

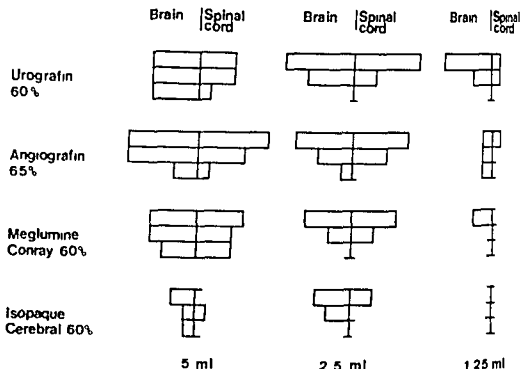


Fig. 2. Survey of the degree of injury to the blood-brain barrier in the different experimental series.

on the same side as the injection. Lesions higher up in the brain stem or in the cerebral hemispheres were sometimes somewhat more obvious on the contralateral side. Microscopic examination of the brain and the spinal cord revealed that the barrier lesions were most marked in the grey substance, even in the spinal cord.

A comparison of the different series indicates that the diatrizoate compounds (Urografin 60 % and Angiografin 65 %) caused similar lesions to the blood-brain barrier and produced seizures in 5.0 and 2.5 ml doses. Conray Meglumin and Isopaque Cerebral never caused seizures in the doses administered. Conray Meglumin led to lesions of the blood-brain barrier to nearly the same extent as the diatrizoate compounds. Isopaque Cerebral seems to give rise to less obvious lesions to the blood-brain barrier but even this contrast medium was not completely atoxic in 2.5 ml doses.

Discussion

Catheterization of the vertebral artery proved to be a difficult procedure and was unsuccessful in twelve cases. A catheter with its tip moulded to a rather open, S shape again proved to be most suitable (OLIN & REDMAN 1967). Anatomic

different contrast media was not especially emphasized but the importance of a prolonged application time on the degree of lesions was revealed It has also been reported (Di Chiro et coll 1970) that meglumine iothalamate is of low toxicity as far as the spinal cord is concerned if no other measures are performed at aortography

Acknowledgement

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SUMMARY

The toxicity of various modern roentgen contrast media in examinations of the brain and spinal cord was investigated by their selective injection into the vertebral artery of rabbits and evaluated by the damage caused to the blood brain barrier The spinal cord was somewhat less vulnerable to contrast media than the brain

ZUSAMMENFASSUNG

Die Toxizitat verschiedener moderner Rontgenkontrastmittel bei den Untersuchung n des Gehirns und des Ruckenmarks wurde durch deren selektive Injektion in die Arteria vertebra lis der Kaninchen untersucht und durch die verursachte Schadigung der Blut Gehirn Barri ere festgestellt Das Ruckenmark war etwas weniger empfindlich gegen die Kontrastmittel als das Gehirn

RÉSUMÉ

La toxicité de differents moyens de contraste radiologique modernes utilises pour l examen du cerveau et de la moelle a ete etudiee en les injectant selectivement dans l artere vertebrale de lapins et en se basant sur les perturbations causees a la barriere hemato encephalique La moelle est un peu moin sensible aux moyens de contraste que le cerveau

REFERENCES

Baker H L Love J G and Layton D D Angiographic and surgical aspects of spinal cord vascular anomalies/Radiology 88 (1967) 1078

Di Chiro G Fried L C and Doppmann J L Experimental spinal cord angiography Brit J Radiol 43 (1970) 19

Djindjian R Houdart R et Hurth M Les angiomes de la moelle Editions Sandoz Paris 1969

Golazé A Soutoul J H et Castaing J Les arteres de la moelle epinière des animaux d ex périmentation Path et Biol 13 (1965) 723

Hol R and Skjerven O Spinal cord damage in abdominal aortography Acta radiol 42 (1954) 276

but less than with Urografin 60 %. Finally, Isopaque Cerebral 60 % effected a minimal rise in the blood pressure although bradycardia occurred with the 50 ml dose, no convulsions appeared. REDMAN & OLIN (1967) in a previous investigation, determined the dose necessary to elicit seizures with injections into the vertebral artery of rabbits. They reported that Isopaque Cerebral had to be injected in higher doses than Urografin 60 % to obtain this effect. The present investigation has revealed that the ranking of the latter two contrast media is the same when lesions of the blood brain barrier are used as the parameter of toxicity. As evident from the tables in the present investigation it is possible to produce damage to the blood brain barrier without seizures. It was stated by WHITELEATHER & DE SAUSSURE (1956) that seizures were a more sensitive measure of toxicity than damage to the blood brain barrier, the opposite has proved to be true in the present investigation. It is known that sodium salts of contrast media interfere more with the general circulation than do meglumine salts (e.g. JEPPSSON & OLIN 1970). The only contrast medium containing sodium salts in the present investigation was Urografin 60 %, it also had the most marked effect on the general circulation. Against its injection into the internal carotid artery a dose of 10 ml was not tolerated when injected into the vertebral artery. This is most probably due to the fact that injection of a contrast medium into the vertebral artery produces damage to centres vital for the respiration and circulation (REDMAN & OLIN 1967). Conray Meglumin and meglumine diatrizoate were of equal toxicity both when injected into the internal carotid artery and the vertebral artery.

The lesions in the spinal cord tended to be somewhat less marked than those in the brain with injection into the vertebral artery. Earlier investigations of the toxicity of contrast media have been limited to the spinal cord alone and usually confined to highly concentrated sodium salts, e.g. sodium trizoate and sodium diatrizoate.

Meglumine iothalamate has, however, recently been tested by aortography in monkeys (DI CHIRO et coll. 1970). The present examination has indicated that lesions to the blood brain barrier are most marked in the grey substance in both the brain and the spinal cord, which is in accordance with earlier examinations (HOL & SKJERVEN 1954, MARGOLIS 1958, JEPPSSON 1962). Previous investigations have been performed as aortographies, as a rule in dogs (MARGOLIS et coll. 1956, 1958, MARGOLIS & YERASIMIDES 1966, KILLEN et coll. 1959, 1960, TORNELL 1968). These have aimed at the development of the angiographic technique to demonstrate the vessels of the spinal cord. The measures that have been employed have either been balloon occlusions of the ascending aorta at a suitable level or reduction of the flow to other organs, e.g. by vasopressor substances, or external compression of the abdomen (DI CHIRO et coll. 1970). The toxicity of

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ANGIOGRAPHY IN CEREBRAL DEATH

by

E BERGQUIST and K BERGSTROM

The diagnosis of cerebral circulatory arrest has gained increasing interest during recent years through discussions on the definition of *death and the* advance in transplantation surgery The demand for a correct diagnosis has become more urgent and in this connection angiography has taken a prominent place Arrest of the cerebral circulation is considered to be a sign of irreversible brain damage nowadays called cerebral death or total cerebral infarction RIISHEDE & ETHELBERG (1953) demonstrated cerebral circulatory arrest by carotid angiography in five patients with tentorial herniation due to an expansive intracranial lesion The same angiographic signs have been described by LOFSTEDT & VON REIS (*1956 1959*) HEISKANEN (1964) and BUCHELER et coll (1970) among others in patients with intracranial injuries or diseases associated with raised intracranial pressure

The aim of this paper is to present the angiographic findings in a consecutive series of patients with a clinical diagnosis of cerebral death

Material A total of 28 patients with a clinical diagnosis of cerebral death (total cerebral infarction) and an isoelectric EEG were investigated The basic diseases of the patients were as follows

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JEPPSSON P. G. Studies on the blood brain barrier in hypothermia. Acta neurol. scand. Suppl. *160 (1962).*
— and OLIN T. Neurotoxicity of roentgen contrast media. Study of the blood brain barrier in the rabbit following selective injection of contrast media into the internal carotid artery. Acta radiol. Diagnosis 10 (1970), 17.
KILLEN D. A. and LANCE L. M. Significance of repeat injection of contrast medium in the genesis of kidney and spinal cord damage resulting from abdominal aortography. Ann. Surg. 152 (1960), 231.
— — and OWENS G. *Relative suitability of Urotron 70 percent and Hypaque 90 percent* for use as aortographic contrast media. Surgery 15 (1959) 436.
MARGOLIS G., TARAZI A. K. and GRIMSON K. S. Contrast medium injury to the spinal cord produced by aortography. Pathologic anatomy of the experimental lesion. J. Neurosurg. 13 (1956) 349.
— TINDALL G. T., PHILLIPS R. L. et coll. Evaluation of roentgen contrast agents used in cerebral arteriography. J. Neurosurg. 15 (1958) 30.
— *and YERASIMIDES T. G. Vaso pressor potentiation of neurotoxicity in experimental aorto*graphy. Acta radiol. Diagnosis 5 (1966) 388.
OLIN T. and REDMAN H. Experimental evaluation of contrast media in the vertebral circulation. Acta radiol. (1967) Suppl. No *270* p. *216*.
TORNELL G. Spinal cord tolerance to roentgen contrast media particularly during aortography with temporary occlusion of the aorta. An experimental investigation in dogs. Acta radiol. Diagnosis 8 (1968) 257.
WHITELEATHER J. E. and DE SAUSSURE R. S. *Experience* with a new contrast medium (Hypaque) for cerebral angiography. Radiology 67 (1956) 537.

four vessel angiography rose to 45 ml, the injection pressure in carotid angiography was 6 kp/cm and in four vessel angiography 7 kp/cm

The following projections and series were the rule In carotid angiography a cervical film in the lateral projection, lateral series over the skull, and frontal series over the skull with the central ray running parallel with the anterior cranial fossa in four vessel angiography the same projections in the cranial series were supplemented over the neck with a frontal series The series took 18 s in carotid angiography and in four vessel angiography 24 s, about 30 min elapsed between the initial and final series Photographic subtraction was a routine procedure

Results

No cerebral circulation was evident in 24 patients (Fig 1) in the remaining 4 patients faint contrast filling of arteries at the base of the skull was obtained Partial filling of an aneurysm arising from the upper part of the carotid siphon was obtained at carotid angiography in 1 patient and in another with a skull injury who had undergone bilateral trephining the middle meningeal artery was filled on the right but not on the left side The right middle meningeal artery was outlined in a patient who had been operated upon for a meningeoma in the left Sylvian fissure a large defect not covered with bone was evident in the frontotemporal region The proximal parts of the right and left anterior and middle cerebral arteries and the inferior posterior cerebellar artery were filled in the fourth patient who had *undergone operation 28 years earlier for a meningeoma* in the posterior cranial fossa and now had a recurrence Four vessel angiography was performed in the 3 last patients

The filling level of the internal carotid artery in 25 of the 26 patients who underwent four vessel angiography (in one of these it was uncertain because no cervical series was obtained) was as follows

Proximal parts of anterior and middle cerebral arteries (1), carotid siphon (3) C1 (7) C2 (5) C3 (8) C4 (1) and level uncertain, but below C3 (1)

Filling of the right ophthalmic artery was observed in one of the 2 patients *who underwent bilateral carotid angiography* although this occurred only in one of the patients in whom four vessel angiography was performed

The level to which the vertebral artery was filled in 22 of the 26 patients subjected to four vessel angiography was Immediately above foramen magnum (1) C1 (5) C2 (10) C3 (1) C4 (2) C5 (2), C6 (1) and level *uncertain* but below C5 (4) (No cervical series was obtained in one patient and in 3 patients the level was vague but below C5) The contrast medium reached the level of C1—C2 in about half of the patients



Fig. 1. Subtraction films. The contrast medium in the internal carotid arteries and vertebral arteries reaches to the base of the skull; no intracranial circulation. The extracranial branches of the external carotid arteries are filled.

Subarachnoid haemorrhage (8), intracerebral haemorrhage (3), cerebral contusion (8), cerebral tumour (4), arteriovenous aneurysm (1), hypoxia (3), and hepatic coma (1).

The criteria for cerebral death were: (1) The cause of the cerebral injury was known, (2) a clinical combination of arrest of ordinary respiration, deep unconsciousness with no automatic motor responses, no reaction of the pupils to light.

Methods. Bilateral carotid angiography was employed in 2 patients and combined with four vessel angiography in 1 patient, four vessel angiography was used alone in 25 patients. The carotid angiographies were performed by direct puncture of the common carotid artery, the location of the puncture needle being checked by cervical radiography. A grey Ödman catheter with side holes was advanced from the femoral artery in the four vessel angiographies until the tip lay in the ascending aorta. Isopaque Cerebral was used in most cases although Urografin 60 % was also sometimes administered. The amount of contrast medium injected per series in carotid angiography was 8 ml and in

ng was only partial and occurred at a late phase with no further move nt Fig 2 a indicates that the level reached by the contrast medium in the otid and vertebral arteries had no relation to the length of the time between establishment of a clinical diagnosis of cerebral death and the angiographic amination

Autopsy disclosed total cerebral infarction in all patients angiography thus ver furnished a false positive result neither was there any correlation between e level reached by the contrast medium and the duration of survival after the giography (Fig 2 b) It would seem that the angiographic examination should carried out as soon as the clinical criteria of cerebral death have been fulfilled nal evidence of the occurrence of cerebral death may then be recorded

Four vessel angiography would appear to be preferable to selective injections simultaneous filling of both the carotid and vertebral arteries is thus obtained echnical complications especially intramural injection may then be excluded s a reason for the absence of intracranial filling Contrast medium is always vailable to the external carotid arteries and filling of the external branches of e e arteries indicates good systemic circulation Each patient may thus be said be his own control The present authors in agreement with others consider hat at least two injections of contrast medium should be given with an interval f about 30 min between each

SUMMARY

The angiographic findings in 28 patients with a clinical diagnosis of cerebral death (total cerebral infarction) and an isoelectric EEG are reported All patients exhibited cerebral circulatory arrest Four vessel angiography is recommended as the most suitable angiographic method for verification of cerebral death

ZUSAMMENFASSUNG

Die angiographischen Befunde bei 28 Patienten mit der klinischen Diagnose eines zerebralen Todes (totale zerebrale Infarcierung) und einem isoelektrischen EEG werden beschrieben Alle Patienten zeigten einen Stillstand der zerebralen Zirculation Eine Vier-Gefass Angiographie wird als am besten geeignete angiographische Methode zum Nachweis des zerebralen Todes empfohlen

RÉSUMÉ

Presentation des signes angiographiques de 28 malades ayant des signes cliniques de mort cerebrale (ramollissement cerebral total) et un EEG isoelectrique Tous ces sujets avaient un arret circulatoire cerebral Les auteurs recommandent l angiographie des quatre arteres comme le meilleur moyen angiographique de verification de la mort cerebrale

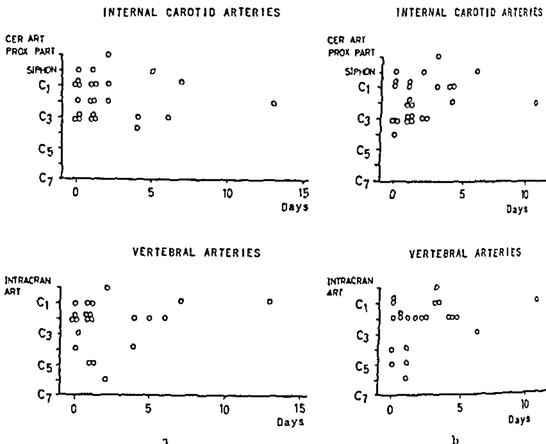


Fig 2 Level of contrast medium in internal carotid arteries and vertebral arteries in relation to the time between establishment of a clinical diagnosis of cerebral death and four vessel angiography (a) and duration of survival after the day of four vessel angiography (b)

Circulation was always present in the extracranial branches of the external carotid artery

Fig 2 a gives the time that elapsed between the clinical diagnosis of cerebral death and the angiographic examination in the patients subjected to four vessel angiography The figure also indicates the level to which the contrast medium reached in the carotid and vertebral arteries The levels also appear in Fig 2 b, but in relation to the duration of survival after the day of angiography

Discussion

Angiography always revealed evidence of the arrest of the cerebral circulation and thus of cerebral death Contrast medium was sometimes evident, it is true, in arterial branches immediately above the base of the skull although this

FROM THE NEURORADIOLOGIC AND NEUROSURGICAL CLINICS OF THE UNIVERSITY OF HELSINKI FINLAND

STENOSIS OF THE AQUEDUCT OF NON TUMORAL ORIGIN

by

M ROUKKULA and V HALONEN

Changes in shape, size and position of the subarachnoid cisterns associated with stenosis of the aqueduct of a benign nature find little place in the literature. Such changes are however important in distinguishing between non tumoral stenosis and infratentorial masses. RUGGIERO (1957) writing of stenosis of the aqueduct stated: L'aspect normal du quatrieme ventricule et des citernes de la fosse posterieure permet d'exclure l'existence d'une tumeur infratentorielle.

Material and Method. The material consisted of 14 patients, 8 of whom were males and 6 females, aged between 6 and 47 (mean age 21.7 years).

Both encephalography and ventriculography were performed in all patients. Five underwent the procedures at the same session and this may have had some effect on the shape, size and position of the cisterns. (Figures in brackets refer to the 5 patients who underwent ventriculography and encephalography at the same session.)

Diagnostic criteria for non tumoral origin of stenosis of the aqueduct. The kink of the aqueduct was within the limits of normal anatomic variation (LIND-

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REFERENCES

Büchner H., Kaufer C. und Dux A. Zerebrale Angiographie zur Bestimmung des Hirntodes. Fortschr. Röntgenstr. 113 (1970) 278.

Heiskanen O. Cerebral circulatory arrest caused by acute increase of intracranial pressure. A clinical and roentgenological study of 25 cases. Acta neurol. scand. (1964) Suppl. No. 7.

Löfstedt S. och von Reis G. Intracraniella lesioner med bilateralt upphävd kontrastpassage i a. carotis interna. (In Swedish.) Opusc. med. 1 (1956) 199.

— — Diminution or obstruction of blood flow in the internal carotid artery. Opusc. med. 4 (1959) 345.

Riishede J. and Ethelberg S. Angiographic appearance in sudden and severe herniation of brain through tentorial incisure. Arch. Neurol. Psychiat. 70 (1953) 399.



Fig   Normal fourth ventricle Compressed cerebellopontine cisterns with left crural cistern somewhat wide and depressed Descending posterior tentorial herniation on left side

Fig 3 Wide sutures normal sella turcica Fourth ventricle somewhat deformed but normal in position

autopsy) an 8 mm narrow part of the aqueduct however lay rostrally from the fourth ventricle

The length of the break in the aqueduct varied from 2 mm to 25 mm in 11 patients the mean length of the gap was 6 mm and in 2 patients it could not be measured

Conventional roentgenograms Signs of increased intracranial pressure were noted in 13 patients Widening of the sutures was evident in 4 of the 5 children under 8 years of age (Fig 3) the sella turcica was normal in 2 of these Eight of the 9 patients over 8 years of age had typical increased pressure signs in the sella turcica the patient with a normal sella turcica had stenosis of the aqueduct

The fourth ventricle The shape and size of the fourth ventricle were normal in 10 and somewhat deformed in 2 patients (Fig 3) in one of these it was a little shortened and in 2 a little smaller than normal The position of the fourth ventricle was normal in 5 patients displaced somewhat downwards and backwards in 9 (Fig 5a) one of these 9 patients being the one with relative stenosis

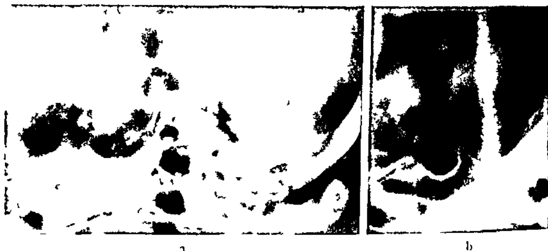


Fig. 1. Congenital stenosis of the aqueduct. a) Encephalography. Wide sulcus chiasmatis. An 8 mm narrow part of aqueduct evident rostrally from the fourth ventricle. Cisterna magna compressed with tip of the tonsil reaching to arch of atlas. Wide quadrigeminal cistern. Mole form of quadrigeminal plate. b) Ventriculography. No filling of aqueduct from third ventricle. No aqueduct in the upper part of pons was evident at autopsy.

GREN & DiCHIRO 1953) in all patients, the length of the quadrigeminal plate varies from 15 to 24 mm (LILIEQUIST 1959). The present authors have estimated the normal and pathologic shapes as well as the size of the quadrigeminal plate from experience gained in lumbar encephalography, (about 200 of which are performed per annum by the LINDGREN method). The shape of the quadrigeminal plate in the lateral view resembles that of LILIEQUIST's figure 55b. It is not kinked, thickened or deformed, the pons is also normal in appearance. These normal findings denote stenosis of the aqueduct and exclude the presence of a tumour around the aqueduct (LINDGREN 1954), autopsy revealed congenital stenosis of the aqueduct in one of the patients. The mean follow up time of the patients was 2 years, no clinical signs pointing to a tumour were observed.

Results

Stenosis of the aqueduct. Classification into congenital and acquired (TAVERAS & WOOD 1964) has not been attempted. Stenosis of the aqueduct was absolute in 13 patients and relative in one patient. The configurations of the rostral end of the aqueduct according to the scheme of SCHECHTER & ZINGESSER (1967) were as follows: Club shaped end in 3 patients (Fig. 6), in one of whom the stenosis was relative. Broad funnel in 9 patients (Fig. 1 a). Narrow funnel in 1 patient. No aqueduct near the third ventricle in 1 patient (confirmed at



Fig 5 Enlarged sella turcica and wide sulcus chiasmatis Normal shape and size of fourth ventricle which is pressed downwards and backwards Compressed cisterna magna and herniated tonsils Compressed interpeduncular and chiasmatic cisterns Mole form of quadrigeminal plate with wide and depressed ambient wing Wide cisterna veli interpositi

Suprasellar cisterns

The interpeduncular cistern This was normal in 5 (2) patients and compressed in 9 (3) patients (Fig 5 a) it was compressed in the patient with relative stenosis

The crural cisterns These were normal in 3 (2) patients wide on one side in 1 (1) patient wide on one side and pressed downwards in 1 patient (Fig 2) and wide on both sides and displaced downwards in 2 (1) patients The cisterns were compressed and displaced downwards in 2 (1) patients (Fig 4 b unilaterally compressed and the other side not filled in 1 patient The cistern was compressed on one side and displaced downwards and not filled on the other side in 1 (1) patient they were faintly outlined in 1 patient and unfilled in 2 patients

Unilateral compression with the opposite side unfilled was evident in the patient with relative stenosis

The chiasmatic cistern This was normal in 3 (1) patients compresssed in 7 (1) and unfilled in 4 (3) patients The cistern was compresssed in the patient with relative stenosis



Fig. 1. a) Broad funnel in rostral end of aqueduct. Third ventricle extends into sella turcica. b) *Compressed* cerebellopontine cisterns with crural cisterns also compressed and depressed. Wide pericallosal cisterns. Symmetric hydrocephalus. Compressed ambient cisterns. Bilateral descending posterior tentorial herniation.

Cisterns of the posterior cranial fossa

Cisterna magna. This was normal in 1 (1) patient and compressed in 13 (4) (Figs. 1 a, 5 a). Herniation is recorded when the tip of the tonsil is at the level of the outer border of the foramen magnum or lower. Herniation was observed in 8 (3) patients (Fig. 1 a), in 3 (2) of whom the tip of the tonsil was level with the outer border of the foramen magnum and in 5 (1) patients was lower. The cisterna magna was compressed and the tonsils herniated in the patient with relative stenosis.

The pontine cistern. This was normal in 7 (4) patients, wide in one and compressed in 6 (1) patients. The pontine cistern was compressed in the patient with relative stenosis.

The cerebellopontine cistern. The cerebellopontine cisterns were normal in 4 (2) and compressed in 9 (2) patients (Figs. 2, 4 b), the right cistern was somewhat wide in one patient. The left cerebellopontine cistern was compressed in the patient with relative stenosis.

The ambient cistern This was of normal width in 7 (2) patients, in one of whom the supratentorial part of the cistern at least was wide The cistern was wide on one side in 2 (2) patients compressed in 4 (1) (Fig 4 b) and faintly filled in 1 patient It was compressed in the patient with relative stenosis

The wings of the ambient cistern These were normal in position and width in 2 (1) patients normal in position but wide in 5 (1) and displaced downwards and backwards and wide in 7 (3) patients (Fig 5 b) The wing was normal in position but wide in the patient with relative stenosis

Cisterna veli interpositi This was wide in 8 (3) patients (Fig 5 b) faintly filled in 1 and unfilled in 5 (2) patients The cistern was wide in the patient with relative stenosis

Tentorial and occipital herniations

Descending posterior herniation in the tentorial notch (AZAMBUJA et coll 1956) was evident in all 14 patients This was unilateral in 6 (3) patients (Fig 2) and bilateral in 8 (2) patients (Fig 4 b)

Descending third ventricle herniation in the tentorial notch (PERRYMAN & PENDERGRASS 1948) was observed in 8 (2) patients in 5 of these with concomitant herniation of the tonsils No third ventricle herniation was present in the patient with relative stenosis

Descending lateral ventricle herniation in the tentorial notch (PERRYMAN & PENDERGRASS) was evident in 3 patients in one of whom it was unilateral and in two patients bilateral symmetric hydrocephalus was particularly large Descending herniation of the third ventricle was present and in bilateral ventricle herniation tonsillar herniation was also evident No lateral ventricle herniation was apparent in the patient with relative stenosis

Herniation of the tonsils was evident in 8 (3) patients (Fig 1 a) in five of whom they were pressed out through the foramen magnum Herniation of the tonsils was present in the patient with relative stenosis

Discussion

LILIEQUIST (1960), dealing with non tumoral stenosis of the aqueduct stated The fourth ventricle is in such cases not displaced backwards or raised nor is the quadrigeminal plate changed or dislocated Furthermore the quadrigeminal



Fig. 6. Ventriculography. Enlarged sella turcica. The rostral end of the aqueduct is club shaped. The cisterna magna and pontine cistern are compressed and the tonsils herniated; the pericallosal cisterns are wide. The quadrigeminal cistern is of normal height. Typical mole form of quadrigeminal plate with bilateral descending posterior tentorial herniation; the ambient cisterns are compressed. The cisterna veli interpositi is wide. (Encephalography, performed ten days before ventriculography, revealed air in the lateral ventricles: relative stenosis of the aqueduct.)

Cisterns of the tentorial notch

The pericallosal cistern. This was of normal width in 2 (1) patients, wide in 10 (3) (Figs. 1b, 5 b) and not outlined in 2 (1) patients. It was wide in the patient with relative stenosis.

All patients had marked hydrocephalus, which in one was slightly and in another distinctly asymmetric. Autopsy of the latter failed to reveal a tumour although congenital absence of the rostral end of the aqueduct was evident.

The quadrigeminal cistern. This was normal in 6 (3) patients, normal in height but with an anterior indentation caused by the pineal recess in 1 patient. The cistern was wide in 4 (1) patients (Fig. 1 a), wide and asymmetric in 1 (1), and faintly filled in 2 patients. It was normal in the patient with relative stenosis.

The quadrigeminal plate. This was never thickened and in 9 patients resembled the figure 55 b of LILIEQUIST (1959). This configuration, seen from the side, is termed the mole form (Figs. 1 a, 5 b). The exact shape of the quadrigeminal plate was difficult to estimate in 3 (2) patients for various reasons and in 2 patients was normal and had no mole form; this was present in the patient with relative stenosis. The quadrigeminal plate was not displaced in relation to the immediate neighbouring structures but where these were moved downwards and backwards the plate naturally shared in the displacement.

The ambient cistern This was of normal width in 7 (2) patients in one of whom the supratentorial part of the cistern at least was wide The cistern was wide on one side in 2 (2) patients compressed in 4 (1) (Fig 4 b) and faintly filled in 1 patient It was compressed in the patient with relative stenosis

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SUMMARY

Both ventriculography and encephalography were performed in 14 patients with stenosis of the aqueduct of non tumoral origin The radiologic findings in conventional skull films and these special examinations are described Descending posterior tentorial herniation is important in differentiating between non tumoral stenosis of the aqueduct and compression due to infratentorial masses

ZUSAMMENFASSUNG

Sowohl die Ventrikulographie als auch die Encephalographie wurden bei 14 Patienten mit einer Stenose des Aquadukts die nicht einen Tumor als Ursache hatte vorgenommen Die radiologischen Befunde von konventionellen Schadelaufnahmen und di die er speziellen Untersuchungen werden beschrieben Eine deszendierende posteriore Tentoriumhernie ist fur die Differenzierung zwischen einer Stenose des Aquadukts die nicht durch Tumor bedingt ist und Kompression die durch unterhalb des Tentorium liegende Massen hervorgerufen ist v e entlich

RÉSUMÉ

Les auteurs on fait une ventriculographie et une encephalographie a 14 malades presentant une stenose de l aqueduc d origine non tumorale Ils decrivent les resultats de la radiographie simple du crane et de ces examens speciaux La hernie descendante postérieure par l incisure de la tente est un élément important du diagnostic differentiel entre la ténose non tumorale de l aqueduc et la compre sion de l aqueduc par une tumeur sous tentorielle

REFERENCES

AZAMBUJA N LINDGREN E and SJOGREN S E Tentorial herniations Acta radiol 46 (1956) 215 224 232

LILIEQUIST B The subarachnoid cisterns Acta radiol (1959) Suppl No 185

— Encephalographic chang s in the axial pressure cone syndrome Acta radiol 54 (1960) 369

— Lumbar encephalography in pontine and intracerebellar tumors Acta radiol Diagnosis 1 (1963) 593

LINDGREN E Some aspects on the technique of encephalography Acta radiol 31 (1949) 161

— Röntgenologie *In* Handbuch der Neurochirurgie Band 2 p 160 Springer Verlag Berlin Gottingen Heidelberg 1954

— and DI CHIRO G The roentgenologic appearance of the aqueduct of Sylvius Acta radiol 39 (1953) 117

PERRYMAN C and PENDERGRASS E Herniation of the cerebral ventricles Amer J Roentgenol 59 (1948) 27

RUGGIERO G L encéphalographie fractionnée Masson et Cie Paris 1957

SCHECHTER M and ZINGESSER L The radiology of aqueductal stenosis Radiology 88 (1967) 905

TAVERAS J and WOOD E Diagnostic neuroradiology Williams and Wilkins Baltimore 1964

cistern is not dislocated but is widened like most of the other cisterns around the brain stem. The fourth ventricle was however displaced downwards and backwards in most of the patients of the present series but never raised. It was a little deformed in 2 patients and in 9 patients the typical 'mole' form of quadrigeminal plate was evident, the position of the latter was not disturbed in relation to the immediate neighbouring structures, which were however themselves usually displaced. The quadrigeminal cistern was often wide as were the pericallosal cisterns, ambient wing cisterns and the cisterna veli interpositi, as reported by LILIEQUIST.

PERRYMAN & PENDERGRASS wrote: 'Posterior herniation of the third ventricle occurs when there is obstruction of the cerebrospinal pathway in the aqueduct of Sylvius or fourth ventricle. Lateral ventricle herniation occurs when there is obstruction of the cerebrospinal pathway in the anterior portion of the third ventricle.'

AZAMBUJA et coll. stated: 'Such a dilatation has, in Sweden at least, been observed only in cases of stenosis of the aqueduct not due to tumour, and it may be regarded as a form of downward tentorial herniation.' The present findings confirm the latter observations, descending herniation of the third ventricle was observed in 8 patients of the present material and with lateral ventricle herniation in 3 patients. Unlike PERRYMAN & PENDERGRASS, whose observations were based on two instances of lateral ventricle herniation, no obstruction of the cerebrospinal pathway in the anterior part of the third ventricle in the 3 patients with lateral ventricle herniation was evident. These, however, had particularly marked hydrocephalus.

Differential diagnosis. Compression of the infratentorial cisterns, particularly of the crural cisterns, caused by non tumoral stenosis of the aqueduct is on the whole more variable and not as general as compression caused by a midline infratentorial tumour, the latter, however, causes dilatation of the cisterns above the tentorial notch more or less similar to that produced by stenosis of the aqueduct. All the patients had descending posterior tentorial herniation. This is a most important differential diagnostic sign because it is unlikely to occur with infratentorial tumours.

The quadrigeminal plate is often kinked or deformed in tumours of the posterior fossa (LILIEQUIST 1963) while the typical 'mole' form of the former is usually present with non tumoral stenosis of the aqueduct.

Widening of the pericallosal cisterns may be observed in both conditions. The symmetric hydrocephalus associated with non tumoral stenosis of the aqueduct is generally marked and in this long lasting condition even descending herniations of the third and lateral ventricles may be observed fairly often.

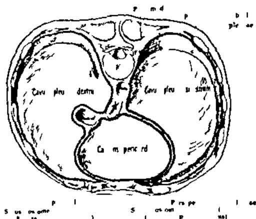


Fig 1 Cross section of the thorax at the level of Th11 The distension of a small space between the vertebral bodies and the mediastinal pleura enables the posterior mediastinum to be reached from behind

directed again t the lateral wall of a vertebral body (Fig 2) the posterior lateral part of the vertebral body being reached, small amounts of CO are injected to widen the space between the vertebral body and the mediastinal pleura A fine guide wire with a oft tip is then introduced through the cannula and gently advanced Any slight resistance to the wire is an indication for its withdrawal from the end of the cannula the latter is then redirected and the position of the guide wire restored These manipulations with repeated gas injections enable the wire to be introduced into the posterior mediastinum It is

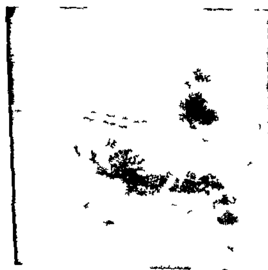


Fig A 2 mm *cannula is introduced* from behind cm lateral to the midline against the lateral part of Th Gas is injected and a metal guide wire gently manipulated through the subpleural space into the poster or med astinum

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR BJÖRN NORDENSTRÖM), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

PARAVERTEBRAL APPROACH TO THE POSTERIOR MEDIASTINUM FOR MEDIASTINOGRAPHY AND NEEDLE BIOPSY

by

B. NORDENSTRÖM

Transjugular (NORDENSTRÖM 1967 a, 1968, 1969) and paraxiphoid (NORDENSTRÖM 1966, 1967 b, 1969) techniques have been described for catheterization, biopsy and contrast examinations of mediastinal structures. The transjugular approach brings the posterior mediastinum within reach. It has been thought, however, that these two methods might be supplemented by a third one from behind, which has also been mentioned (NORDENSTRÖM 1970). This possibility has been further explored and found to be useful in certain pathologic conditions; it will now be described in connection with the examination of conditions of the oesophagus.

Method. A section of the normal chest at the level of Th11 appears in Fig. 1. A narrow space is present between the vertebral body and the mediastinal pleura and through this instruments can be introduced into the posterior mediastinum.

The patient lies prone on the examination table. A 1.5 to 2 mm injection cannula is introduced under local anaesthesia and TV monitoring about 5 cm lateral to the midline posteriorly at the level of Th9 to Th11. The cannula is

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Fig 4 Case 2 Barium in the oesophagus with gas injected through a catheter in the mediastinum Narrowing of the lower part of the oesophagus and a hiatus hernia The walls of the oesophagus and the herniated part of the stomach are not thickened The appearances suggest an inflammatory stricture

extent was as often impossible to evaluate paravertebral catheterization with gas insufflation around the oesophagus was performed

Two oblique views of the oesophagus during a barium swallow and the injection of carbon dioxide into the perioesophageal tissue appear in Fig 3 The carbon dioxide was subsequently replaced by about 300 ml oxygen injected through the same catheter The thickness of the tumour is indicated by the outline of its interior and exterior margins The oesophageal wall was thickened approximately 8 cm above the tumour (Fig 3 b)

Case 2 Male aged 60 with difficulty in swallowing for three years Oesophagoscopy failed to reveal signs of malignancy Therapeutic dilatation was performed on several occasions for presumably constrictive oesophagitis although without permanent cure As the possibility of submucosal malignancy increased posterior mediastinography with gas inflation was performed The paravertebral approach was used for the introduction of a catheter through which carbon dioxide and then oxygen were injected

A double-contrast examination revealed a narrowed lower part of the oesophagus (Fig 4) The narrow part was rigid and continuous with a small hiatus hernia of the stomach The catheter introduced by the paravertebral route appears to advantage in Fig 4 b A suitable projection was also chosen to demonstrate the walls of the herniated stomach and

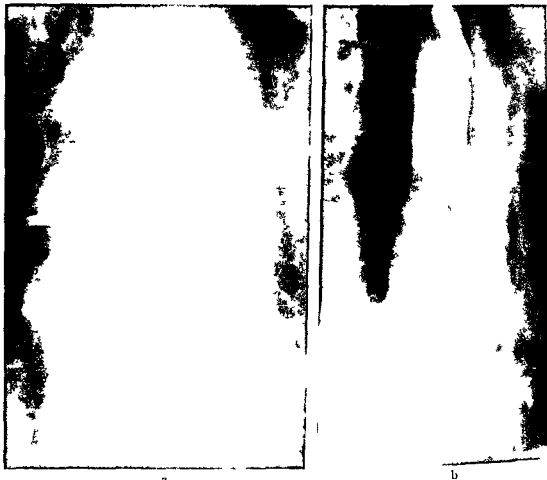


Fig 3 Case 1 a) A catheter is introduced into the posterior mediastinum by means of the guide wire Barium outlines the interior extension of an adenocarcinoma b) Gas injected into the paraoesophageal tissue through the catheter reveals that the oesophageal wall is thickened for a distance of 8 cm above the upper pole of the interior extension of the tumour

then used for the introduction of a catheter which can later be directed to different parts of the posterior mediastinum and used for the injection of gas, contrast medium etc

The catheterization technique has also been used successfully for the sampling of cell material from lymph nodes in the subcarina region and the oesophageal wall Its diagnostic possibilities will be illustrated

Case reports

Case 1 Male aged 54 with difficulty in swallowing for three months A barium swallow examination revealed a neoplasm at the lower part of the oesophagus A specimen obtained at oesophagoscopy indicated the presence of a highly differentiated adenocarcinoma As its



Fig 6 Same case as in fig 5 Transthoracic transpulmonary bi opsy was performed with a 16 cm long 0 9 mm ordinary needle from behind An ul er crater in the anterior oe ophageal wall was utilized as a landmark The cell material aspirated indicated that the les on in fact was inflamma tory

anteriorly A small amount of gas around the oesophagus indicated the thickness of the wall The absence of any general increase in the outer contour of the wall was in favour of an inflammatory lesion and against a neoplasm

An attempt was made to confirm the diagnosis by gas inflation around the oesophagus with a paravertebral approach supplemented by needle biopsy The introduction of a needle through the catheter was however unsuccessful due to the site of the lesion although the sampling of cells from the oesophageal wall was performed The patient lay prone on the examination table while an ordinary 16 cm long 0 9 mm needle for transthoracic aspiration n edle biopsy was introduced under local anaesthesia from behind at the level of the ophageal narrowing through the lower lobe of the l ft lung as far as the oesophagus Some of the barium remaining in the ulcer crater served as a landmark for the needle biopsy Fig 6) so that the lumen of the oesophagus could be avoided The material aspirated from the pliable oesophageal wall contained only inflammatory cells A small pneumothorax o curred after withdrawal of the needle as commonly happens in ordinary transthoracic bi psy Operation revealed ulceration with scarring

Complications A mall pneumothorax was produced by insertion of the guide wire in one of the cases the air was left to be re orbed spontaneously It was assumed that only the parietal pleura was perforated or ruptured by the gas o that an increase in the amount was unlikely The development of symptoms would have demanded the introduction of a suction tube The gas in the pleura after the transthoracic transpulmonary insertion of a needle to reach the oe ophageal lesion was minimal and expected

Conclusion

The technique of mediastinal catheterization with gas inflation of the posterior mediastinum described seems to be of value in the differential diagnosis and



Fig 5 Case 3 a) A double contrast examination revealed no changes in the upper and middle parts of the oesophagus b c) Irregular narrowing of the lower part b) The gas injected in the paraoesophageal tissue disclosed that the wall of the oesophagus was slightly thickened but not bulging suggesting an inflammatory stricture

oesophagus Both had regular inner and outer contours at the site of the narrowing No signs to suggest an expanding growth were evident These findings appeared to indicate an inflammatory stricture and no attempts were therefore made to introduce an instrument through the catheter for sampling of tissue or cell material This is however a relatively simple procedure with the instruments earlier described in reports on transthoracic needle biopsy and the paraxiphoid approach to the mediastinum (DAHLGREN & NORDENSTROM 1966 NORDENSTROM 1967)

Case 3 Male aged 63 with difficulty in swallowing pain in the chest and a rapidly deteriorating general condition Roentgen examination of the oesophagus revealed an irregular narrowing 5 cm in length of the lower part of the oesophagus Oesophagoscopy with biopsy was performed on six occasions but a conclusive diagnosis was considered unlikely the patient probably had a malignant growth of the oesophagus and due to his poor condition was not a good candidate for surgery He was finally subjected to mediastinography with gas inflation around the oesophagus and biopsy of the diseased part of the oesophagus An ordinary double contrast examination disclosed normal appearances of the upper and middle parts of the oesophagus (Fig 5 a) with the lower part constricted excepting where it was expanded by the barium (Fig 5 b c) a shallow ulcer was present

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OPTIMUM PHOTON ENERGY IN ORDINARY RADIOGRAPHY OF THE LARYNX

by

ANDERS HEMMINGSSON and HANS LUNDQVIST

The soft tissue of the larynx is defined radiographically by its contrast against the adjacent air The cervical spine is always superimposed upon the larynx in a frontal roentgenogram of the region This film contains closely spaced density variations due to the different radiation absorption within the spongy bone and variations at wider intervals i e due to spinous processes The laryngeal structures may be distinguished from the latter by slightly altering the projection The fundamental problem in frontal radiographic examination of the larynx is however the disturbance in the film caused by the trabeculae of the spongy bone

The difference in contrast between soft tissue and air and soft tissue and bone may be varied in radiologic examinations by changes in the energy spectrum of the roentgen photons The linear attenuation at low energies is greater in bone than in soft tissue whereas at higher energies the difference is much less A high voltage technique with a tube potential of 150 kV or more has therefore been re

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determination of the extent and type of certain lesions of the oesophagus It may be supplemented with sampling of cell material

SUMMARY

A paravertebral approach to the mediastinum through the space between the vertebral bodies and the mediastinal pleura after its distension with carbon dioxide is described Gas or a positive contrast medium may then be injected for the examination of the posterior mediastinum or for the performance of needle biopsy A case of malignancy and two cases of inflammatory lesions illustrate the usefulness of the procedure

ZUSAMMENFASSUNG

Ein paravertebraler Zugang zum Mediastinum durch das Gebiet zwischen den Vertebralkorpern und die mediastinale Pleura nach deren Dehnung mit Karbondioxid wird beschrieben Gas oder ein positives Kontrastmittel kann dann zur Untersuchung des hinteren Mediastinums oder zur Durchfuhrung einer Nadelbiopsie injiziert werden Ein Fall von Malignitat und zwei Falle von entzundlichen Lasionen illustrieren die Brauchbarkeit dieses Verfahrens

RÉSUMÉ

L'auteur décrit une voie d'approche paravertebrale sur le médiastin par l'espace compris entre les corps vertebraux et la plevre mediastinale quand elle est distendue par l'injection de gaz carbonique On peut alors injecter un gaz ou un moyen de contraste positif pour examiner le mediastin posterieur ou pour faire une biopsie à l'aiguille L'utilite de cette technique est illustree par un cas de tumeur maligne et deux cas de lesions inflammatoires

REFERENCES

DAHLGREN N and NORDENSTROM B Transthoracic needle biopsy Almqvist & Wiksell *Stockholm 1966*

NORDENSTROM B Percutaneous catheterization of the pericardium Acta radiol Diagnosis 4 (1966) 662

— (a) Transjugular approach to the mediastinum for mediastinal needle biopsy Invest Radiol 2 (1967) 134

— (b) Paraxiphoid approach to the mediastinum for mediastinography and mediastinal needle biopsy Invest Radiol 2 (1967) 141

— Percutaneous insertion of extracardiac pacemaker electrodes Invest Radiol 3 (1968) 285

— New trends and technics in roentgen diagnosis of bronchial carcinoma *In* Frontiers of pulmonary radiology p 380 Grune & Stratton New York 1969

— Mediastinal lymph node biopsy *In* Progress in lymphology p 143 Georg Thieme Verlag Stuttgart 1970

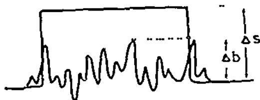


Fig 2 Film density profiles of a soft tissue structure Δs and spongy bone Δb

and the reported mass densities of spongy bone ranges from 1 15 (JACOBSON & KNAUER 1956) to 1 65 g/cm³ (HAAS & SANDBERG 1957)

The eye is able to perceive a difference in light intensity of about 2 per cent at the light level usually used in inspection of roentgenograms (JOHNS & CUNNINGHAM 1969) corresponding to a difference in film density of 0 0086 An object with a diameter of 2 mm may thus be perceptible at a viewing distance of 20 cm (STURM & MORGAN 1949) It is mainly the contour of an object that stimulates the eye brain system (WALLS 1954) The gradient zone between areas of different photographic densities in the roentgenogram is thus primarily registered by the eye (TUDDENHAM 1957 JACOBSON & STUART MACKEY 1958 LITTLETON & WINTER 1965) The differences in photographic density due to different radiation absorption in the structures thus constitute a reasonable measure of how well the corresponding structures will be outlined

The perception of one structure is also dependent on the presence of other such structures (MORGAN 1945 TUDDENHAM 1957 and others) The bone disturbance due to spongy bone may be regarded as a high frequency noise It may be reasonable to assume that the contour of the homogeneous soft tissue object in Fig 2 may be separated from the superimposed bone disturbance due to spongy bone when the photographic density difference Δs is greater than Δb in the immediate vicinity of the contour The difference must also amount to at least 0 0086

Measurement in roentgenograms of bone trabeculae and marrow spaces of spongy bone

Material Thirty roentgenograms of the larynx in frontal and lateral projections evenly distributed between the sexes and between the age groups 20 to 30, 40 to 50 and 60 to 70 years were obtained with a focus of 1 2 to 2 0 mm a film focus distance of 1 0 to 1 5 m and a tube potential of 70 to 90 kV The potential was 150 kV with 1 mm brass filtration in another series comprising 30 frontal films all the other parameters were unchanged

Method The widths of 10 trabeculae of different orientations and the shortest distances between them were measured in each film at the level of the larynx with the aid of a magnifying glass with an inbuilt scale

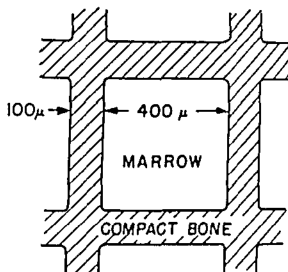


Fig 1 Model and dimensions of bone trabeculae and marrow spaces in spongy bone (From ICRU Report 10 d)

commended in the examination of soft tissue structures outlined by air and with inhomogeneous bone in the roentgen beams (STEPHANI 1929, WACHSMANN et coll 1952, TUDDENHAM et coll 1953, 1954, McDONNEL et coll 1958, BEIQUE & ROTENBERG 1965 and others) The potential most suitable for these radiographic examinations remains however still undecided

Every radiographic examination provides an optimum photon energy spectrum determined by the geometric and chemical properties of the object and the demand for diagnostically favourable contrast in the film (WEGELIUS 1954, TUDDENHAM 1957) HENRIKSON (1967) calculated the optimum photon energy for demonstrating dental cavities in teeth and LASFIL et coll (1968) investigated the fact that low energies are useful in revealing small changes in radiation absorption or chemical composition No similar work appears to have been conducted on soft tissue structures with superimposed spongy bone It was therefore considered reasonable to attempt to calculate the optimum energy for a simplified model of the larynx in the frontal projection Consideration was also paid to the disturbance' produced by the spongy bone in the cervical spine

Anatomic and physiologic considerations The soft tissue components of the neck may be accepted as having attenuation properties equivalent to those of water and a mass density of 1 0 g/cm³ (SPIERS 1946) The widths of the trabeculae in spongy bone of a cervical vertebra are 60 to 100 μm (1 000 μm = 1 mm) according to ENGSTROM et coll (1958) and the widths of the medullary spaces between them 250 to 950 μm The trabeculae are built up of compact bone and lie perpendicularly to one another (Fig 1 from ICRU Report 10d, 1962) The mass density of compact bone is about 1 85 g/cm³ (SPIERS 1946)

Methods The mass attenuation coefficients including coherent scattering for bone and water were taken from ATTIX & ROESCH (1968) The mass density of the bone was presumed to be 1 85 g/cm³ (SPIERS 1946) and of the soft tissue 1 0 g/cm³ The attenuation in the air filled cavity was neglected The gradient of the film was presumed to be 3 0 and the density of the film to lie within the straight part of the characteristic curve

The thickness (b) of the soft tissue component (B) and of the compact bone (G) in the bone component (A) of the model was fixed at 1 mm for determination of the optimum photon energy for demonstrating the air filled cavity in the model Monoenergetic photons fluence Φ_0 with energies from 20 to 10 000 keV were presumed to impinge upon the model The emerging photon fluences Φ_1 I Φ_2 (Fig 3) produced in the film the densities D_1 D_2 D respectively The effect of scattered radiation was disregarded.

The density differences $D - D_1$ and $D_3 - D$ indicate how clearly the wall of the air filled cavity and the bone component respectively should appear The difference in radiation absorption between the air filled cavity and its soft tissue wall as registered by the film should be as large as possible with at the same time the contrast of the bone equally low The quotient $f_1 = \frac{D - D_1}{D_3 - D}$ is thus an indication of the clarity of the wall in relation to the bone disturbance It is also postulated that $D - D_1$ should be greater than $D_3 - D$ and $D_2 - D_1$ greater than 0 0086 for the wall to be visible

According to eq (5) in the Appendix the quotient f_1 is given by the relation

$$f_1 = \frac{D - D_1}{D_3 - D} = \frac{\gamma (\log \Phi - \log \Phi_1)}{\gamma (\log \Phi_3 - \log \Phi)} = \frac{\log \Phi - \log \Phi_1}{\log \Phi_3 - \log \Phi} \quad (1)$$

where γ = the average gradient of the characteristic curve of the film

Substituting Φ_1 Φ and Φ_2 (cf Fig 3) with eq (3) in the Appendix gives

$$f_1 = \frac{d \mu_e \rho_v}{b\mu_b \rho_b - b\mu_e \rho_e} = \frac{d\mu \rho_e}{b(\mu_b \rho_b - \mu_e \rho_e)} \quad (2)$$

where b = the thickness of the inhomogeneous bone layer d = the thickness of the air filled cavity μ = the mass attenuation coefficient for water in cm²/g, μ_b = the mass attenuation coefficient for bone in cm²/g ρ = the mass density of water in g cm⁻³ ρ_b = the mass density of bone in g cm⁻³

This means thus that f_1 is dependent on the thickness of the inhomogeneous bone layer (b) the thickness of the air filled cavity (d) and the linear attenuation coefficient for water and bone

Calculations of the smallest visible soft tissue structure (E) in the air filled cavity of the model were performed for monoenergetic photon energies between

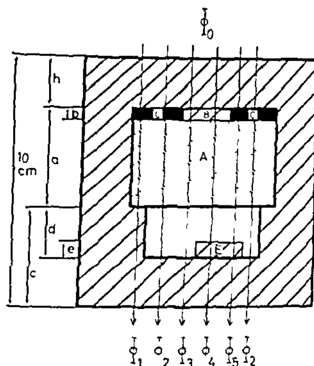


Fig 3 Cervical model for calculation of the optimum photon energy for demonstrating the walls of the air filled cavity and the smallest visible soft tissue structure within it
□ soft tissue ■ compact bone
□ spongy bone □ air

Calculations of optimum photon energy and smallest visible soft tissue structure

Model Calculations were made for a simplified theoretic model of the neck in order to determine the photon energy at which the walls of the larynx may best be evaluated in the frontal projection This was presumed to be constructed of soft tissue, bone and an air filled cavity (Fig 3) The difference in photographic density between different parts of a roentgenogram of the model was used as a measure of how clearly its components would appear in a radiologic examination The inhomogeneity of the spongy bone tissue in a cervical vertebra (Fig 2) was simplified in the model so that this was recorded as only two equal differences in density of the film To achieve this, the 4 cm thick bone component (A in Fig 3) included a layer of soft tissue (B) with variable thicknesses of its sides, surrounded by compact bone (G) simulating trabeculae of the same thickness (b) as the soft tissue (B) The remaining parts of the bone component (A) were presumed to consist of spongy bone not producing any difference in radiation absorption The cross section (d) of the air filled cavity in the model was 2 cm, the rest of the model consisted of soft tissue which gave it a total thickness of 10 cm A soft tissue structure (E) of variable thickness was also presumed for calculations of the smallest visible structure in the air filled cavity at different energies (Fig 3)

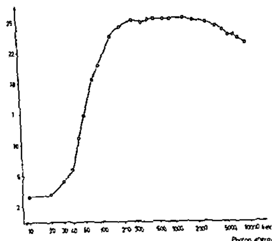


Fig 4 The quotient fs at different photon energies as a measure of the visibility of the air filled cavity in the model

filled cavity the criteria for that of the soft tissue structure (E) viz. $\Delta s > \Delta b$ and $\Delta s > 0.0086$ are fulfilled at 30 keV when it is 4.8 mm thick at 50 80, 200 and 1 000 keV the criteria are fulfilled with soft tissue of 2.9, 2.1 1.8 and 1.8 mm respectively The thickness of the visible soft tissue was always greater at 1.5 MeV than at 1 MeV

With a thickness of more than about 0.2 mm (b) of the inhomogeneous bone layer the thinnest visible soft tissue structure was always evident at the higher energies 200 to 1 000 keV (Fig 5) With an inhomogeneity of about 0.1 mm the tissue must be greater at 500 and 1 000 keV than at 200 keV to produce the density difference 0.0086 the thickness of the thinnest visible soft tissue at this bone inhomogeneity is the same for 80 and 200 keV The soft tissue visible will be smaller at lower energies for a bone inhomogeneity below 0.1 mm

Discussion

Size of trabeculae and marrow spaces of spongy bone in roentgenograms The values obtained for the width of the trabeculae of 0.4 to 1.4 mm and of the space between them of 0.4 to 1.6 mm are greater than the corresponding values obtained by ENGSTRÖM et coll (1958) in a cervical vertebra They are however in agreement with the results obtained by ROCKOFF (1967) who in microdensitometric measurements of lumbar vertebrae in roentgenograms reported that the widths of the trabeculae without magnification in vitro was 0.4 to 0.6 mm, the

Table

Width of bone trabeculae and marrow spaces in roentgenograms of cervical vertebrae

Age (years)	Width of bone trabeculae (mm)				Width of marrow spaces (mm)	
	Frontal projection		Lateral projection		Frontal projection	
	Mean	Range	Mean	Range	Mean	Range
20—30	0.7 ± 0.1	0.4—1.2 ± 0.1	0.9 ± 0.1	0.4—1.2 ± 0.1	1.0 ± 0.1	0.4—1.6 ± 0.1
40—50	0.9 ± 0.1	0.6—1.4 ± 0.1	0.9 ± 0.1	0.4—1.4 ± 0.1	1.0 ± 0.1	0.4—1.6 ± 0.1
60—70	0.9 ± 0.1	0.4—1.6 ± 0.1	0.9 ± 0.1	0.4—1.4 ± 0.1	0.9 ± 0.1	0.4—1.6 ± 0.1

20 and 10 000 keV The calculations were made for thicknesses from 0.02 to 2.0 mm of the inhomogeneous bone layer (B) and (G) Fig 2 indicates that for the contour of the soft tissue structure (L) in the air filled cavity of the model to be distinguishable, the difference in photographic density of the contour, $\Delta s = D_3 - D_1 = D_2 - D_0$ must be greater than that of the 'bone disturbance' $\Delta b = D_3 - D$ (Fig 3) Furthermore Δs must be greater than 0.0086

Results

Size of trabeculae and marrow spaces of spongy bone in roentgenograms The mean width of the trabeculae in the frontal and lateral projections proved to be 0.7 to 0.9 mm in different age groups The ranges of the individual widths were 0.4 to 1.6 and 0.4 to 1.4 mm in the frontal and lateral projections, respectively The mean distance between the trabeculae in the frontal projection was 0.9 to 1.0 mm with a range of 0.4 to 1.6 mm (Table) There was no difference between the results at 70 to 90 kV and at 150 kV with 1 mm brass filtration

Optimum photon energy and smallest visible soft tissue structure The quotient f_1, as a measure of visibility of the air filled cavity in the model, increases rapidly with increasing photon energies up to 150 to 200 keV (Fig 4) It rises only slightly above 200 keV, is almost constant between 300 keV and 1.5 MeV, a slow decrease takes place between 1.5 MeV and 10 MeV The contrast of the wall of the air filled cavity, $D_2 - D_1$, was always greater than that of the bone disturbance, $D_3 - D$, and over 0.0086

The results of the calculations of the smallest visible soft tissue structure (L) in the air filled cavity of the model at a bone inhomogeneity of 0.02 to 2.0 mm thickness (b) are given in Fig 5 With an inhomogeneity of e.g. 1 mm, which value was used for calculation of the optimum energy for visibility of the air

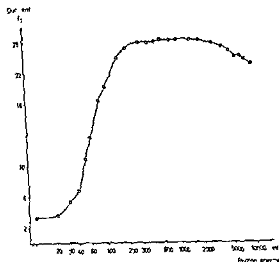


Fig 4 The quotient f_1 at different photon energies as a measure of the visib lity of the air filled cavity in the model

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With a thickness of more than about 0 2 mm (b) of the inhomogeneous bone layer the thinnest visible soft tissue structure was always evident at the higher energies 200 to 1 000 keV (Fig 5) With an inhomogeneity of about 0 1 mm the tissue must be greater at 500 and 1 000 keV than at 200 keV to produce the density difference 0 0086 the thickness of the thinnest visible soft tissue at this bone inhomogeneity *is the same for* 80 and 200 keV The oft tissue visible will be maller at lower *energies for a bone* inhomogeneity below 0 1 mm

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Optimum photon energy and smallest visible soft tissue structure. The quotient f_1, as a measure of visibility of the air filled cavity in the model, increases rapidly with increasing photon energies up to 150 to 200 keV (Fig. 4). It rises only slightly above 200 keV, is almost constant between 300 keV and 1.5 MeV, a slow decrease takes place between 1.5 MeV and 10 MeV. The contrast of the wall of the air filled cavity, $D_2 - D_1$, was always greater than that of the bone disturbance $D_3 - D_2$, and over 0.0086.

The results of the calculations of the smallest visible soft tissue structure (I) in the air filled cavity of the model at a bone inhomogeneity of 0.02 to 2.0 mm thickness (b) are given in Fig. 5. With an inhomogeneity of e.g. 1 mm, which value was used for calculation of the optimum energy for visibility of the air

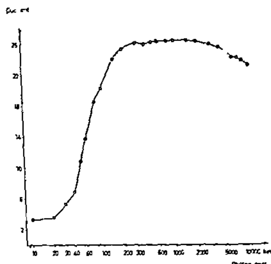


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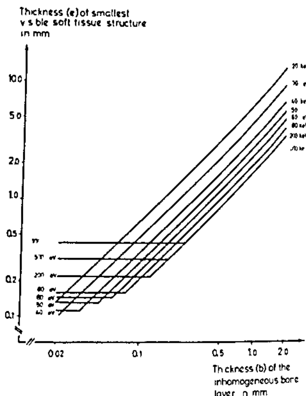


Fig. 5. The smallest visible soft tissue structure in the air filled cavity of the model at varying degrees of bone inhomogeneity and different photon energies. The difference of 0.0086 of the soft tissue structure (I) at different photon energies is indicated by the horizontal lines. Above a bone inhomogeneity of about 0.2 mm the smallest visible soft tissue structure is given by the same line for the 200, 500 and 1 000 keV energies.

size of the focal spot was 1.0 mm. No correction was made for the geometric enlargement and the size of the focal spot was 1.2 to 2.0 mm, which may explain the somewhat different results of the present investigation. It is also probable that the trabeculae observed in the roentgenogram corresponded to a few partly overprojected trabeculae in the vertebra (FRANKE 1941, 1942, CHANTRAINE 1942, RESINK 1949, NEWELL & GARNEAU 1951 and ROCKOFF 1967).

Optimum photon energy and smallest visible soft tissue structure. The model in Fig. 3 is a rough simplification of the cross section of a neck at the level of the larynx. The geometric and radiophysical properties of the different components agree, however, with the anatomic region that they are to simulate. The effect of scattered radiation in the roentgenogram was disregarded, since small apertures of the diaphragm and grids are used in roentgenography of the larynx.

The criteria for visibility are hypothetical. In the calculation of optimum energy for demonstration of the air filled cavity in the model, the only requirement of importance is that the contrast of the air filled cavity should be as large as possible while at the same time that of the bone should be as low as possible, i.e. a maximum signal to noise ratio (LYSFLI et coll. 1968). In the calculation of the smallest visible soft tissue structure at different energies it was assumed

that the contrast of the soft tissue structure should be greater than that of the bone The absolute values however can be supposed to vary for different objects due for example to different orientation and configuration of the structures (NEWELL & GARNEAU 1951)

The conclusions that the air filled cavity may be outlined best at energies above 150 keV (Fig 4) concur with the results of frontal cervical phantom investigations at 50 kV (~ 20 to 30 keV) to 200 kV combined with a 2 mm brass filter (~ 100 to 150 keV) in which a 25 mm air filled cavity was best demonstrated at the highest potential A round rod or pellet of soft tissue equivalent material with a diameter of 3 mm and 6 mm respectively in this cavity was similarly partly visible only at the higher energies and their diameters had to be more than twice as large to be evident at 50 kV (HEMMINGSSON to be published) This is in agreement with the results of the calculations of the thinnest soft tissue structure visible in the air filled cavity at a bone inhomogeneity of 1 mm where it was found that soft tissue approximately 2 mm thick was theoretically visible at 100 to 200 keV while it had to be almost 5 mm thick to be apparent at 30 keV (Fig 5)

Photon energies above about 200 keV produce very little change in the contrast conditions (Fig 4) Much improvement of the diagnostic possibilities in radiographic examination of air filled cavities with inhomogeneous bone in the direction of the beam cannot therefore be expected with still higher energies not at least due to the increase of scattered radiation This is also evident from Fig 5 in which the thickness of the smallest visible soft tissue structure in a laryngeal cavity is about the same at 200 500 and 1 000 keV when the thickness of the inhomogeneous bone layer (b) is more than about 0 2 mm At 500 and 1 000 keV furthermore the contrast of soft tissue compared with air is lower than at 200 keV which is illustrated by the fact that its thickness (e) must be greater in order to produce the difference in radiation absorption resulting in a photographic density of 0 0086 with a small bone disturbance thickness (b) (Fig 5)

If the thickness of the soft tissue layer (B) and of the compact bone (G) which simulate the inhomogeneity of the bone in the model vary the same course of the curve as in Fig 4 is always obtained as is evident from the fact that

$$f_1 = \frac{D_2 - D_1}{D_3 - D} = \frac{d \ \mu_v \varrho_v}{b \ (\mu_b \varrho_b - \mu_v \varrho_v)}$$

It is probable furthermore that the trabeculae that are reproduced in the roentgenogram and constitute the bone disturbance have a thickness of about 0 5 mm in the direction of the beam (Fig 1) if they are reproduced over

projected, the thickness will be greater. A reasonable value for the thickness of the soft tissue component in the bone part of the model may therefore be considered to be about 1 mm, which value was used in the calculations of the optimum energy for demonstration of the air filled cavity. Bone disturbance with thicknesses of 0.02 to 2.0 mm were used in the calculations of the smallest visible soft tissue structure in this cavity.

Appendix

Monoenergetic radiation has been presumed to penetrate the model in the calculations of *the optimum photon energy for demonstration of the air filled cavity*. When photon radiation is transmitted through an object its fluence decreases owing to attenuation of the radiation according to Lambert's law, whereby

$$\Phi = \Phi_0 e^{-\mu d} \tag{3}$$

where Φ_0 = the fluence of the incident radiation, Φ = the fluence of the transmitted radiation, e = the base of the natural logarithmic system ($e = 2.718$), μ = the linear attenuation coefficient in cm^{-1} for the object at this energy, d = the thickness of the object in cm.

The mass attenuation coefficient in $cm^2 \, g^{-1} = \frac{\mu}{\varrho}$, where ϱ = the mass density in $g \, cm^{-3}$.

If the fluence of the transmitted radiation is Φ_1 and Φ_2 then the radiographic contrast of the object, expressed as the difference between the photographic densities in the roentgenogram, is the difference between the natural logarithms for Φ_1 and Φ_2. When this radiation is recorded in roentgenograms the photographic density within *the straight part* of the characteristic curve of the film is proportional to Φ_1 and Φ_2 (ATTIX & KOTSCH 1968), i.e.

$$D_1 = k \cdot \log \Phi_1, \; D_2 = k \cdot \log \Phi_2 \tag{4}$$

where k is dependent, among other things, upon the gradient of the film and the energy of the beam.

The difference between the photographic density is an expression of the radiographic contrast of the object, i.e.

$$\text{radiographic contrast } D_1 - D_2 = k \, (\log \Phi_1 - \log \Phi_2) \tag{5}$$

If the linear attenuation coefficients of an object and the thicknesses of its components as well as the gradient of the characteristic curve of the film are known, the radiographic contrast of an object may be calculated.

SUMMARY

Variations in photographic density in frontal films of the larynx were determined by measurements with a magnifying glass with an inbuilt scale of the cervical spine. Calculations made on a theoretic cervical model indicated that a photon energy of about 150 to 200 keV affords the best means of evaluating the walls of an air filled cavity such as the larynx and of small soft tissue structures located within it.

ZUSAMMENFASSUNG

Variationen der Filmschwarzung bei frontalen Filmen des Larynx wurden durch Messungen mittels eines Vergrösserungsglases mit einer eingebauten Skala der Halswirbel bestimmt Berechnungen angestellt an einem theoretischen Halsmodell zeigen dass eine Photonenergie von etwa 150 bis 200 keV am geeignesten ist die Wände einer luftgefullten Kavitat wie die d s Larynx zu beurteilen

RÉSUMÉ

Les variations de noircissement sur les radiographies de face du larynx *ont été determinees* par d s mesures effectuées avec une loupe et une échelle inco porée de la *colonne cervi*cale Le calculs faits sur un modèle theorique de cou ont *montre que* c est une energie photonique d environ 150 à 200 keV qui donne les *meilleures conditions d étude des* parois d une cavite remplie d air telle que le larynx et contenant des *tissus mous*

REFERENCES

ATTIX F H and ROESCH W C Radiation dosimetry Second edition Vol 1 Academic Press New York *London 1968*

— — Radiation dosimetry Second edition Vol 2 Academic Press New York *London* 1968

BRIQUE R A and ROTENBERG A D Effect of filtration *in diagnostic radiology* J Canad Ass Radiol 16 (1965) 59

CHANTRAINE H Ist das Rontgenbild eine echte Abbildung oder nur eine Summationswirkung? Fortschr Röntgenstr 66 (1942) 89

— Der Nachweis der raumlichen Darstellung *der* Knochenbalkchen im Rontgenbilde Fortschr Rontgenstr 66 (1942) 98

ENGSTROM A BJORNERSTEDT R CLEMEDSON R J and NELSON A Bone and radiostrontium Almqvist & Wiksell Stockholm 1958

FRANKE H Streuung und Superposition als zerstörende *und aufbauende Elemente* der Bildgebung Gedanken uber die *Grenzen der* Darstellbarkeit im Rontgenbilde Fortschr Rontgenstr 64 (1941) 288

— Antwort auf die Erwiderung *Chantraines* Fortschr Röntgenstr 66 (1942) 96

HAAS L L and SANDBERG G H Modification of *the depth* dose curves of various radiation by interposed bone Brit J Radiol 30 (1957) 19

HEMMINGSSON A Roentgenologic methods *in examination* of the larynx Comparative phantom investigations in the frontal projections *To be published in* Acta radiol Diagnosis

HENRIKSON C O Iodine 125 *as a radiation source* for odontological roentgenology Acta radiol (1967) Suppl No 269

ICRU Report 10 d Clinical dosimetry National Bureau of Standards Handbook 87 Washington D C 1962

JACOBSON L F and KNAUER I *Absorption* in diff rent tissues of Cobalt 60 gamma radiation and roentgen rays with half value layers from *1mm Al to* 5 mm Cu Radiology 66 (1956) 70

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FROM THE DEPARTMENTS OF ANATOMY AND ODONTOLOGIC DIAGNOSTIC RADIOLOGY, UNIVERSITY OF GOTHENBURG AND THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY III, SAHLGRENSKA SJUKHUSET GOTHENBURG, SWEDEN

DEVELOPMENT OF SPURIOUS CONTOURS OF SPHERICAL AND CYLINDRICAL OBJECTS IN TOMOGRAHPY

by

SVEN REICHMANN

Tomography is a method of body section radiography devised by GROSSMANN (1935 a b) and is similar to planigraphy (BARTELINK 1933 ZIEDSES DES PLANTES 1933) The methods are essentially of equal value (KIEFFER 1939) but tomography has slowly become the predominant term regardless of the design of equipment (cf EDHOLM 1960 WESTRA 1966) The principles now discussed are valid for both types of body section radiography so that the term tomography in its wider sense will be used throughout

Only one plane within the object the tomographic plane should be depicted sharply by tomography If part of an object lies outside the tomographic plane it will be registered with an unsharpness that increases with the distance between the tomographic plane and the object part in question For object parts near the tomographic plane the unsharpness may be so low as to be tolerated by the eye (POSCHL 1940) so that the tomogram actually contains information not only from an infinitely thin plane but from a zone the tomographic zone

The focus and film move synchronously along a defined movement path

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JACOBSON B and STUART MACKAY R Radiological contrast enhancing methods Advanc biol med Phys 6 (1958) 201

JOHNS H E and CUNNINGHAM J R The physics of radiology Third edition Charles C Thomas Publisher Springfield Illinois 1969

LITTLETON J T and WINTER F S Linear laminagraphy A simple geometric interpretation of its clinical limitations Amer J Roentgenol 95 (1965), 981

LYSELL C MÅRTENSSON B K A and ONSELL K A Determination of small mass differences in roentgenography I Theoretical considerations Acta radiol Ther Phys Biol 7 (1968) 42

McDONNELL G M BERMAN H L and LODMELL E A Supervoltage roentgenography Amer J Roentgenol 79 (1958) 306

MORGAN R H An analysis of the physical factors controlling the diagnostic quality of roentgen images Part II Maximum resolving power and resolution coefficient Amer J Roentgenol 54 (1945) 395

NEWELL R R and GARNEAU R The threshold visibility of pulmonary shadows Radiology 56 (1951) 409

RESINK J E J Is a roentgenogram of fine structures a summation image or a real picture? Acta radiol 32 (1949) 391

ROCKOFF S D Radiographic trabecular quantitation of human lumbar vertebrae in situ I Theory and method for study of osteoporosis Invest Radiol 2 (1967) 272

SPIERS F W Effective atomic number and energy absorption in tissues Brit J Radiol 19 (1946) 52

STEPHANI J De l'emploi de l'antidiffuseur pour les radiographies pulmonaires J Radiol Électrol 13 (1929) 393

STURM R E and MORGAN R H Screen intensification systems and their limitations Amer J Roentgenol 62 (1949) 617

TUDDENHAM W J The visual physiology of roentgen diagnosis Amer J Roentgenol 78 (1957) 116

— HALE J and PENDERGRASS E P Supervoltage diagnostic roentgenography A preliminary report Amer J Roentgenol 70 (1953) 759

— GIBBONS J F HALE J and PENDERGRASS E P Supervoltage and multiple simultaneous roentgenography New technics for roentgen examination of the chest Radiology 63 (1954) 184

WACHSMANN F BETHGE K und BUCHHEIM E Grundlagen und Ergebnisse der Hartstrahltechnik Fortschr Röntgenstr 76 (1952) 147

WALLS G L The filling in process Amer J Optom 31 (1954) 329

WEGELIUS C The diagnostic use of high voltage rays in relationship to the physical background of mass absorption Acta radiol (1954) Suppl No 116

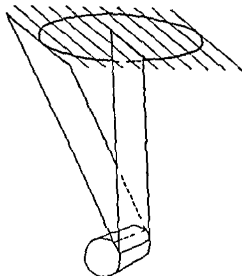


Fig 1 Circular tomography of a cylinder with the axis parallel with the tomographic planes. Different parts of the surface are depicted when the focus is at different points of its movement path The points belonging to the different tomographic planes may be connected by means of parallel lines

roentgenogram formed when the system was motionless and a tomogram superimposed The ordinary roentgenogram will then give rise to contours from absorption boundaries outside the tomographic zone Such bizarre movements naturally do not occur in any tomographic system but the same effect will arise if the movement path be constructed in such a way that the roentgen ray intensity is higher in some incidental angles than in others Both the form of the movement path and the speed of the tube film system in different parts of the movement are then important (KIEFFER 1939 MATTSSON 1972) It may also be mentioned that POSCHL (1940) described spurious contours from structures outside the tomographic zone caused by fluctuations in the tube voltage due to incomplete rectification of the alternating current

The properties of a tomographic system thus largely depend on the form of its movement path A comparison between four commonly available tomographic movements will be considered these are the linear elliptical circular and hypocycloid movements and how they differ in depicting the cylindrical and spherical absorption boundaries will be demonstrated Although comparisons between different movements have been carried out earlier (KIEFFER 1939 STIEVE 1957 EDHOLM 1960 CZEMPIEL 1962 LITTLETON 1964 MATTSSON 1972) no investigation has so far been published where all these movements have been tested for these types of absorption boundary Special regard will be given to the problem of spurious contours

during the exposure in most tomographic procedures When the focus is at different points of its movement path, the central roentgen ray will strike the midpoint of the tomographic plane at different incidental angles The angle between the central roentgen rays when the focus is at two extreme opposite points of its movement path is called the tomographic angle

The contours in tomography as well as in conventional radiography always correspond to absorption differences within the object, the contour itself being formed where two organs or tissues with different absorption properties for roentgen rays meet, the surface where this meeting occurs is called an absorption boundary The *effect of roentgen rays upon a given object* is thus largely determined by the form of the external and internal absorption boundaries since they define the contours of the image All such absorption boundaries *may in principle be regarded as built up by cylindrical or spherical surfaces* (EDHOLM 1960) The depiction of cylindrical and spherical surfaces is thus the essential factor when the image formation is to be investigated An absorption boundary may be produced as a sharp contour only if it be hit tangentially by the roentgen rays This statement is valid also in tomography (DE WAARD 1938) As the beam direction changes continuously in tomography, the formation of a contour will occur only during that part of the total exposure when the corresponding boundary is so struck (EDHOLM 1960)

One major artefact in tomography is the occurrence of sharp contours formed by absorption boundaries situated far outside the tomographic zone Such contours are especially obvious in linear tomography and are often called parasite shadows As the term contour seems to be preferable, a distinction will be made in this communication between true contours, which correspond to absorption boundaries within the tomographic zone, and spurious contours formed by absorption boundaries outside this zone

There are two main occasions when spurious contours arising from structures outside the tomographic zone develop, namely when the tomographic movement is parallel with an absorption boundary outside the tomographic zone or when the roentgen ray intensity is inhomogeneous during the exposure (MATTSSON 1972) The first factor gives rise to the well known artefacts evident in linear tomography (KIEFFER 1939) *The whole movement does not need to be parallel* with the boundary, however, the same effect may occur to a smaller degree if only part of a multidirectional movement be parallel with a boundary outside the tomographic zone (KIEFFER 1939, MATTSSON 1972)

The influence of intensity variations during the exposure may best be imagined with the focus film system remaining stationary during a considerable part of the exposure time The rays of one *incidental angle* will then be more intense than those of the other angles The result will consist of a conventional

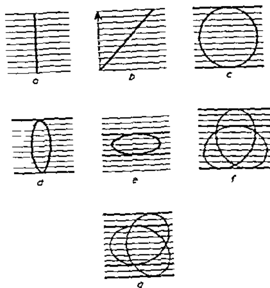


Fig 2 Different tomographic movement paths with the same type of lines superimposed as in fig 1 Thick lines indicate parallelism between cylinder surface and direction of movement. In (b) the linear movement path is not perpendicular to the cylinder axis but the tomographic effect is determined by the perpendicular component (arrow)

relative to the cylinder surface (Fig 2 b) The tomographic effect is then determined by that component of the movement perpendicular to the cylinder surface If the angle between the cylinder and the movement path is 0° tomography is not obtained but spurious contours from the only site of the cylinder surface struck by the tangential roentgen rays will appear in planes on both sides of this site

Circular movement (Fig 2 c) is clearly apt to cause spurious contours. The tomographic plane whose intersecting line passes through the centre of the circular movement path is depicted when the movement is perpendicular to the surface of the cylinder In the other tomographic planes the focus movement is not so sited and in the outermost planes a parallelism between the movement path and the cylinder occurs This means that the middle tomographic plane through the cylinder is registered without errors while the outermost planes may give rise to spurious contours producing the impression that the cylinder is depicted in a zone wider than it really is Moreover the spurious contours from the outermost planes may also interfere with the registration of the planes that lie between them

The drawbacks of the circular movement are also encountered in elliptical tomography (Fig 2 d e) Spurious contours are most likely to arise when the major axis is parallel with the axis of the cylinder (Fig 2 e)

Areal tomography is a somewhat vague term often encountered Strictly

General aspects of the method of analysis

A theoretic analysis has been supported by experiments to prove or illustrate the results The principles of a simple case will first be examined both theoretically and practically a cylinder is tomographed in planes parallel with its axis

Theoretic analysis I

This analysis is based on Figs 1 and 2 Fig 1 explains the principle utilized in Fig 2 *where the different tomographic movements are compared* A cylinder is tomographed by means of a circular tomographic movement, the axis of the cylinder lying parallel with the tomographic plane However, this plane is *not defined*, but *instead two planes at different levels* are *marked* by lines along the cylinder surface The surface in each one of these planes can give rise to a contour in the tomogram only when the roentgen rays strike the surface tangentially Two tangent planes were therefore constructed and were continued to the plane of the movement path The points of intersection between the movement path and one tangent plane thus mark the only focus locations from which the cylinder surface can be registered in the corresponding tomographic plane The parallel lines across the movement path suggest the presence of other tomographic planes not marked on the cylinder surface Some conclusions may be drawn It is evident that the whole cylinder surface cannot be depicted since many tangent planes from the upper and lower parts of the cylinder will pass outside the tomographic movement path It is apparent that an increasing tomographic angle will make a greater part of the cylinder surface accessible It also arises that the direction of the focus movement relative to the cylinder surface may be examined for each tomographic plane if the corresponding intersecting line is compared with the direction of the focus movement at the moment of registration Above all it will be easy to determine whether the focus movement for any tomographic plane is parallel with the cylinder surface at that moment

The same conditions are *supposed to be present in Fig* 2 as in Fig 1, but only the movement paths appear together with the intersecting lines, which are all parallel with the cylinder surface Parallelism between cylinder surface and focus movement, which is one prerequisite for the development of a spurious contour, is marked by a thick intersecting line

The linear movement (Fig 2 a) is well suited for the tomography of a cylinder if the movement path is perpendicular to the surface of the cylinder and the angular velocity is constant No part of the movement is parallel with the surface of the cylinder The movement path may have an angle less than 90°

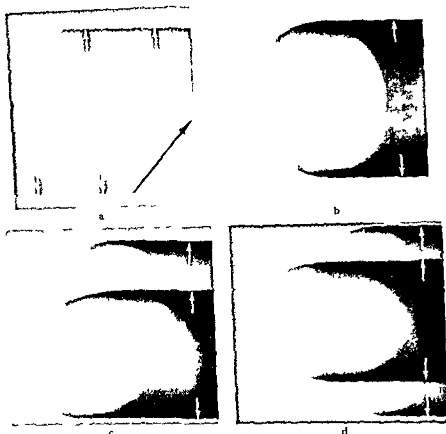


Fig 4 Slit hole camera films formed with a) linear b) circular c) and d) two hypocycloid alternative movements The linear movement is indicated by the large arrow in (a) Only the lateral end of the original roentgenogram appears where the termination of the slit hole produced figures similar to the movement paths the true summation image continuing to the right of these figures Small arrows indicate changes in the roentgen ray intensity sufficiently abrupt for the generation of spurious contours in tomography of a cylinder

Practical tests I

These tests were based on the above analysis They were performed in two steps roentgenography with a slit hole camera and tomography of plexiglass and metal cylinders The test equipment in these experiments as well as in those described later was a Polytome type U The movements used were linear 50° circular 36° elliptical 40 and hypocycloid 48° The stability was tested by means of a sloping metal wire grid and was found to be good for all types

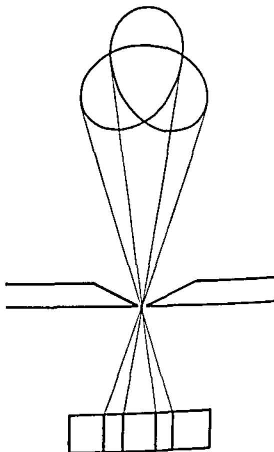


Fig. 3. Image generation in the slit hole camera. A hypocycloid movement path lies above the slit hole and the film where intense bands of blackening correspond to where the movement path and the slit hole are parallel is shown below the hole.

speaking, it occurs only when the movement path is constructed in such a way that the focus by its movement will cover a continuous area during the exposure. Such tomographs have not yet been constructed and the term is often used for certain complicated multidirectional movements such as scanning, spiral and hypocycloid movements. This is done because these, more than the circular and elliptical movements approach the areal condition, the movement path for any given tomographic angle being longer than with the linear, circular and elliptical movements (BAILR 1964). The risk of the development of spurious contours is at a minimum in true areal tomography (KIEFFER 1939, MATTSSON 1972). As regards the hypocycloid movement, Fig. 2 f, g indicates that the risk of the development of spurious contours is not eliminated. The basis for this statement is twofold. Some planes are depicted from more focus passages than other planes, which means that an inhomogeneity of the roentgen ray intensity should occur, and in three or four planes a parallelism between the cylinder surface and part of the movement path takes place.

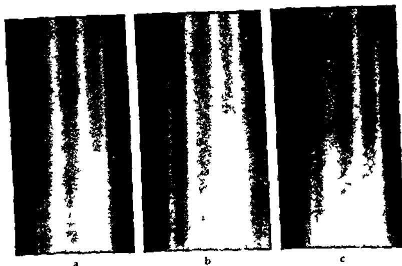


Fig 6 Spurious contours from the lower plexiglass cylinder pair in Fig 5 The movements are a) linear b) circular and c) hypocycloid the last corresponding to the alternative (f) in fig 2 The contours in (b) did not differ appreciably from the true ones in the plane through the centre of the cylinder The unsharpness in (a) is more clearly visible in fig 7 A splitting of the contours on one side in (c) corresponds to the double thick lines in the upper end of the movement path in fig 2f

metal cylinders each in one direction these producing tomograms identical to those of the plexiglass cylinders Their higher contrast enabled their detail to be examined more easily The tomographic planes fell both inside and outside the zone of the cylinders where the roentgen rays could strike their surfaces tangentially in the latter instance no contours would have been visible if no spurious ones had been generated Likewise no contours would have arisen from the cylinders outside the tomographic planes The cylinder positions and movement paths used are presented in Fig 2 b to g

Spurious contours appeared in all types of tomography They occurred both at the border between areas of total and partial absorption of the rays and where the areas ended Only the former contours were of any significant contrast and will be the only ones described The spurious contours arising only from the plexiglass part of the lower cylinder pair in linear circular and hypocycloid tomography appear in Fig 6 In linear tomography the contours corresponded to the beginning and the end of the exposure as in the metal cylinder tomogram In circular and elliptical tomography it was difficult to determine whether the contours were true or spurious In hypocycloid tomography this differentiation was easier the spurious contours being usually double although not always so (cf Fig 6 c) Such contours gradually lost their distinctness with increasing

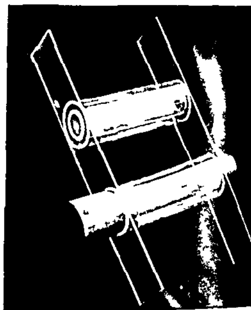


Fig. 5. The two double hollow plexiglass cylinders placed as in the actual experiment described. The tomographic planes all ran through the lower pair where the cylinders had been extended by metal cylinders of the same width.

of movement. The focus size was 0.6 mm × 0.6 mm, tube potential 43 kV. The film, Kodak RP, was developed in a roll machine.

The slit hole camera was placed with the hole in the tomographic plane, the film being in a stationary position below the slit. Thus tomography was not performed but an image was obtained from the slit hole. This image wandered over the film surface when the focus moved during the exposure. The circumstances illustrated in Fig. 2 were thus imitated, the slit hole being parallel with the intersecting lines and the same movements as in Fig. 2 b to g were tested. *Fig. 3 illustrates how the image emerged when a hypocycloid movement was used* and Fig. 4 depicts those obtained by means of the linear, circular, and hypocycloid movements. The theoretic analysis described was thus confirmed, elliptical movement gave corresponding results.

The slit hole camera test disclosed that all movements could give rise to spurious contours as analysed. However, it did not reveal if the spurious contours generated by the different tomographic movements should be equally easy to detect in the tomogram. The manner in which the spurious contours differed *in unsharpness and contrast was therefore investigated, this being performed* by means of tomography of hollow plexiglass and metal cylinders.

A phantom consisting of two pairs of concentric hollow plexiglass cylinders parallel with each other and the tomographic planes was used (Fig. 5). The lower cylinder pair was traversed by all the tomographic planes, the other lying completely outside them in a position obliquely above the lower cylinder pair. The pair of cylinders in the tomographic planes was extended by concentric

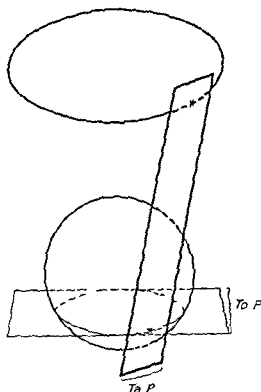


Fig 8 Circular tomography of a sphere The movement path is viewed from above To P — tomographic plane Ta P — tangent plane

movement path This means that if this plane is lowered into the zone where no true contours can be formed spurious contours from the tomographic plane mentioned will appear instead The same applies to elliptical tomography but no single tomographic plane from which all spurious contours are formed will then occur, this is because the surface sector accessible to registration varies in different directions owing to variations in the tomographic angle This is maximal in the direction of the major axis of the elliptical movement path This means that the surface of the sphere will be represented by true contours in the largest possible sector in this direction of the tomographic sweep The sweep over the spherical surface along the minor axis will be at a minimum Moreover the spurious contours generated in this case when the focus movement is parallel with the major axis, will possess higher contrast than spurious contours formed when the focus is at other points of its movement path This difference is due to the fact that the movement path in these situations has a minimum curvature



Fig 7 Spurious contours (arrows) in tomograms of metal cylinders with a) linear and b) circular movement The difference in unsharpness is evident

distance between object and tomographic plane, as was evident when the two cylinder pairs were compared

One remarkable difference between the spurious contours created by the linear movement and the others was evident (Fig 7) The spurious contours in the multidirectional movements all had a lesser degree of unsharpness than those in linear tomography where the unsharpness was marked

As a concluding remark to the analysis and tests above, it may be stated that all the movements examined could give rise to spurious contours These were most evident in circular and elliptical tomography, less obvious in hypocycloid and least apparent in linear tomography As against other methods the number of spurious contours of hypocycloid tomography was usually double

Theoretic analysis II

To determine whether the facts presented are applicable to every kind of absorption boundary, tomography of spheres and cylinders oriented at random will be discussed

A circular tomography of a sphere is reproduced in Fig 8 Just as was shown theoretically for the cylinder, tangent planes to the upper and lower parts of the sphere will pass outside the movement path Thus these parts of the sphere cannot be registered, provided the projection or the tomographic angle remains unchanged The actual tomographic plane is at its lowest where the surface can still be hit tangentially by the roentgen rays The tangent planes through surface points in this tomographic plane will thus coincide with part of the

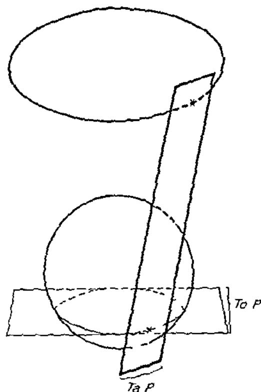


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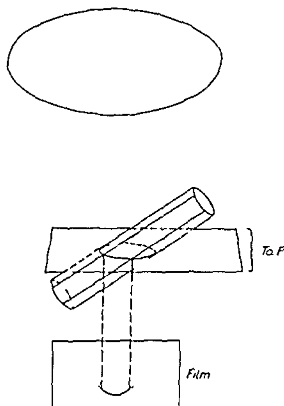


Fig 9 Circular tomography of a slanted cylinder The two lines along the cylinder surface indicate the zone at the anterior side of the cylinder that may be hit tangentially by the roentgen rays This zone in the film plane below is depicted with true contours while spurious ones will make a continuation in both directions caused by the cylinder parts outside the tomographic plane (To P)

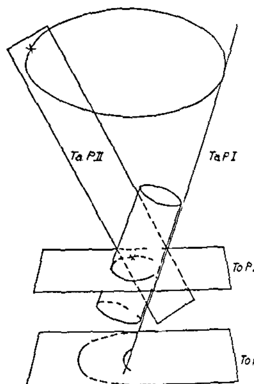


Fig 10 Circular tomography of a slant[ed] cylinder where the whole surface may [be] struck tangentially Owing to the inclin[a]tion of the cylinder the tangent plane (Ta P I) will be parallel both with th[e] movement path and the cylinder surfac[e] this does not occur with tangent plane I[I] The whole circumference of the cylinder [is] depicted in tomographic plane I (To I) with true contours but spurious conto[urs] are also formed as is evident in tomograph[ic] plane II The form of these spurious con[tours] is determined by the form of both th[e] object and the movement path

Linear movement is elliptical where the minor axis of the ellipse is zer[o] Surface parts parallel with the major axis, i e with the direction of movement will then give rise to obvious spurious contours while other parts of the spher[e] — mainly those perpendicular to the movement path — will bring about fain[t] spurious contours at the beginning and at the end of the exposure

Hypocycloid tomography differs from circular tomography only in that th[e] circle of the latter is split up into a system of arches It is evident from Fig 8 however, that spurious contours would be likely to occur It is also probabl[e] from the cylinder tomograms described that the spurious contours would b[e]

double in most places each contour being less evident than the spurious contours generated in circular tomography

Circular tomography of a cylinder whose axis is not parallel with the tomographic plane is represented in Figs 9 and 10 The whole circumference of the cylinder surface cannot be struck tangentially by the roentgen rays although more of the surface can be depicted than would have been possible if the cylinder axis had been parallel with the tomographic planes (Fig 9) The true contours would not end blindly but be continued by spurious contours in both directions these contours are marked by interrupted lines in the figure

When the whole cylinder surface can be hit tangentially by the roentgen rays as in Fig 10 the cylinder part along tangent plane I will be parallel with the corresponding part of the movement path If the cylinder is small as compared with the movement path the same will apply to the opposite part of the cylinder surface i e the part situated at 180° to the one touched by the tangent plane in the figure The anterior and posterior parts of the cylinder surface are parallel with tangent plane II and will be registered when the focus moves at a greater angle to the tangent plane True contours will occur in a tomographic plane through the cylinder such as tomographic plane I but if the plane is lowered into position II spurious contours corresponding to tangent plane I will appear The same spurious contours will in fact be present in tomographic plane I as well in tomographic plane II these are marked both by continuous and interrupted lines in Fig 10 This differentiation has been made to indicate that the unsharpness of the contours should be least in the centre and increase in both directions of the contour It is especially important to note that the spurious contours in tomographic plane II will obtain their form not only from that of the absorption boundaries but from the movement path as well The form of these contours will thus change when the tomographic movement is altered

Another special case of absorption boundary has to be considered namely the plane surface This surface may be regarded as a cylinder or a sphere with an infinitely large radius so that this type of absorption boundary will be depicted by true and spurious contours in the same way as described for other surfaces There is one important difference, however A cylinder or a sphere with a short radius may have many tangent planes that all pass through the movement path of the focus (Fig 1) The plane absorption boundary can of course only have one tangent plane the continuation of the absorption boundary itself The probability of a plane absorption boundary giving rise to spurious contours must therefore be relatively small in comparison with curved ones The plane absorption boundary should not only be parallel with part of the movement path but its single tangent plane should also pass through it The

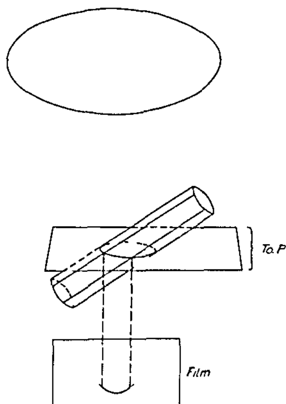


Fig 9 Circular tomography of a slanted cylinder The two lines along the cylinder surface indicate the zone at the anterior side of the cylinder that may be hit tangentially by the roentgen rays This zone in the film plane below is depicted with true contours while spurious ones will make a continuation in both directions caused by the cylinder parts outside the tomographic plane (To P)

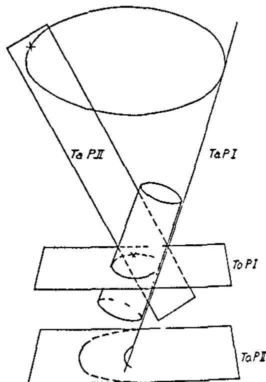


Fig 10 Circular tomography of a slanted cylinder where the whole surface may be struck tangentially Owing to the inclination of the cylinder the tangent plane I (Ta I I) will be parallel both with the movement path and the cylinder surface this does not occur with tangent plane II The whole circumference of the cylinder is depicted in tomographic plane I (To P I) with true contours but spurious contours are also formed as is evident in tomographic plane II The form of these spurious contours is determined by the form of both the object and the movement path

Linear movement is elliptical where the minor axis of the ellipse is zero Surface parts parallel with the major axis, i e with the direction of movement, will then give rise to obvious spurious contours while other parts of the sphere — mainly those perpendicular to the movement path — will bring about faint spurious contours at the beginning and at the end of the exposure

Hypocycloid tomography differs from circular tomography only in that the circle of the latter is split up into a system of arches It is evident from Fig 8, however, that spurious contours would be likely to occur It is also probable from the cylinder tomograms described that the spurious contours would be



Fig 11 Tomograms in a plane through a slanted cylinder as in fig 9 The movements are a circular and b) hypocycloid The transition zon between true and spurious contours is impossibl to locate in (a) but appea in (b) owing to the splitting up and separation of the spurious contours

of ab orption boundaries depicted in the tomographic plane (b) the properties of the spurious contours

Roentgen rays of homogeneous inten ity should strike the object from an infinite number of incidental angles within the limits et by the tomographic angle This will ensure the ideal regi tration of many differently oriented ab orption boundaries with a given tomographic angle and occurs only in true areal tomography With linear movement differences in orientation of the ab orption boundaries are compensated for by the tomographic sweep in one plane only the roentgen ray inten ity in different incidental angles will however be constant or practically o More ab orption boundaries will be registered but the intensity of the roentgen rays will not be homogeneous when the multi directional movements tested are u ed One con equence in hypocycloid tomography will often be a reduction in the useful tomographic angle Figs 2 g and 4 d indicate that absorption boundaries registered from the central zone between the inner pair of thick lines in Fig 2 g are formed by four focus pa ages they will thus stand out much more clearly in the tomogram than those produced only by the outer zones of the movement path where only two pa sages are pos ible

Spurious contours cau ed by parallelı m between absorption boundaries and the tomographic movement path are to be expected even in the most com plicated tomographic movement with the exception of the true areal one The contrast of such a contour depends on the size of the total roentgen dose forming it If this fraction is made sufficiently low — achieved through an appropriate construction of the movement path — the spurious contour will

low probability of plane absorption boundaries giving rise to spurious contours is thus due to the reduction in number of possible planes. On the other hand only single spurious contours will arise from plane absorption boundaries when such contours really are formed. The duplication of the spurious contours evident in hypocycloid tomography of cylinders and spheres cannot be expected since the single tangent plane can pass only through one of the two parts of the movement path that may be parallel with the absorption boundary.

Practical tests II

The tests in this series were all designed on the principles discussed in the last theoretic analysis (Figs. 8, 9, 10).

A hollow sphere of plastic material was tomographed with linear, circular, elliptical, and hypocycloid movements. The tomographic plane was placed outside the object so that all contours could be regarded as spurious. The results fully confirmed the previous discussion. The differences between the movements demonstrated for the cylinders in test series I were thus found also to be valid in tomography of a spherical object. Two slanted hollow plexiglass cylinders (Figs. 9, 10) were tomographed with circular, elliptical, and hypocycloid movements only, the effects of different linear movements being regarded as comparatively easy to envisage. When the whole cylinder surface could not be struck tangentially (Fig. 9) effects of the type in Fig. 11 were obtained. It should be noted that with circular and elliptical movements (Fig. 11 a) the true contours continued into the straight spurious contours so imperceptibly that it was difficult to locate the point where the change took place. The spurious contours with the hypocycloid movement were split up in the same way as in the former investigations (Fig. 11 b). This made the differentiation between true and spurious contours much easier. Spurious contours occurred in tomographic planes outside the object with the cylinder in the positions as in Fig. 10 in accordance with the theory.

A plane lamella of plexiglass was tomographed by means of hypocycloid movement. The tomographic plane lay outside the object so that only spurious contours could be formed. Different orientations of the lamella were employed. Spurious contours arose when the tangent plane of the lamella went through a part of the movement path parallel with the surface. Only single spurious contours were generated from the plane absorption boundary.

Discussion

Since all the tomographic movements tested have proved to generate spurious contours it might be asked if they possess the same value. Two aspects will be considered in the final comparison between the movements, (a) the number

the other hand by low unsharpness in linear as well in multidirectional tomography

The spurious contours gradually fade when the distance between object and tomographic plane is increased A similar effect may be produced if the distance be kept constant and the tomographic angle be increased Such contours may therefore be expected to be especially disturbing in zonography where small tomographic angles are used This partly explains the necessity of a fairly wide free zone between the object to be examined and the objects to be blurred (WESTRA 1966) It is thus also obvious that the free zone must be especially wide if the disturbing object gives rise to high absorption differences WESTRA compared the linear and circular movements for zonographic tasks, concluding that the circular movement was preferable indeed very satisfactory As might be expected from the present investigation the aptness of the circular movement to cause spurious contours is so great as to make it highly desirable that zonographs of a more areal type of movement be developed (Fig 12)

The investigation has disclosed one important property of the spurious contours which should be kept in mind in the choice of tomographic movement namely the recognizability of the spuriousness. If spurious contours cannot be avoided they should at least be possible to recognize as artefacts In this respect the movements tested differ remarkably The greatest disadvantage of linear tomography is not the spurious contours which are easy to recognize but that so few absorption boundaries are depicted and that the width of the tomographic zone varies so much with the orientation of the absorption boundary (MATTSSON 1971) These drawbacks are eliminated to a certain degree in circular and elliptical tomography when it is often impossible to differentiate between true and spurious contours A certain inhomogeneity of the roentgen ray intensity as described will probably reduce the useful tomographic angle for low contrast objects in hypocycloid tomography The spurious contours generated will however usually be clearly recognizable owing to their being double

Acknowledgements

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SUMMARY

Artefacts produced by different types of tomographic movement were investigated The generation of so called spurious contours received particular attention. These arise in all types of tomographic movement and certain differences between them caused by variations in the movement were demonstrated Linear circular elliptical and hypocycloid movement as tested with objects with cylindrical and spherical surfaces.



Fig 12 Zonogram through the common bile duct Circular movement The vertebral bodies are surrounded by double sharp spurious contours owing to the properties of the circular movement The contours correspond to the outer limits of the total and partial absorption of the roentgen rays

be so poor in contrast as to be imperceptible against the over projecting true contours and against the quantum mottle of the radiographic system The visibility of a spurious contour is thus a matter of the signal/noise ratio as described by MORGAN (1966) for other contours The conclusions may therefore be drawn that absorption boundaries with a high absorption difference will reveal the disadvantages of a given tomographic movement better than absorption boundaries with a low absorption difference This explains the recognized fact that skeletal tomography makes higher qualitative demands on tomographic blurring than pulmonary tomography As for the multidirectional movements tested, the hypocycloid movement proved to be somewhat better than the circular and elliptical ones, the spurious contours having a lower contrast at those sites where they were double

Spurious contours arise in linear tomography at the beginning and the end of the exposure These possess much greater unsharpness than the other spurious contours discussed and this probably explains why such little interest has been given to this question All spurious contours caused by parallelism between an absorption boundary and the movement path are characterized on

FROM THE RESEARCH LABORATORIES OF BRACCO INDUSTRIA CHIMICA S P A , MILAN ITALY

PHARMACOLOGIC PROPERTIES OF A NEW ORAL CONTRAST MEDIUM FOR CHOLECYSTOGRAPHY

by

G ROSATI P DE MICHELI and P SCHIANTARELLI

Iopanoic acid (HOPPE & ARCHER 1953) has been the most widely used oral cholecystographic agent for nearly twenty years although several new compounds have been proposed and introduced in clinical practice in the mean time

The compound produces satisfactory filling of the gallbladder in most cases with doses producing scant secondary effects It does not however by any means possess the ideal characteristics given by HOPPE (1959) for this category of diagnostic products this has justified the continuous search for new iodine compounds in the hope of finding one that is less toxic more markedly bili tropic, and better absorbed than iopanoic acid An examination of over 300 compounds synthetized in our Research Laboratories, pointed to the interesting pharmacologic and toxicologic properties of 2 {2 [3 (N ethyl acetamido) 2 4 6 triiodophenoxy] ethoxy} propionic acid, coded B 8890 (Swiss Pat No 483262)

Submitted for publication 7 June 1971

ZUSAMMENFASSUNG

Artefakte, die durch verschiedene Typen tomographischer Bewegung hervorgerufen werden, wurden untersucht. Der Entstehung sogenannter falscher Konturen wurde besondere Beachtung gewidmet. Diese treten bei allen Formen tomographischer Bewegung auf und gewisse *Unterschiede* zwischen diesen, hervorgerufen durch Veränderungen der Bewegung, wurden nachgewiesen. Lineare, zirkuläre, elliptische und hypocykloide Bewegungen wurden mit Objekten mit cylindrischen und sphärischen Oberflächen geprüft.

RÉSUMÉ

L'auteur a étudié les artefacts produits par divers types de mouvements tomographiques. Il a particulièrement étudié la genèse de ce qu'on appelle les faux contours; ils apparaissent *avec tous les types de mouvements tomographiques*. L'auteur montre certaines différences de faux contours dues aux différences de mouvements tomographiques. Il a étudié les mouvements linéaire, circulaire, elliptique et hypocycloïdal au moyen d'objects ayant des surfaces *cylindriques et sphériques*.

REFERENCES

BAUER, H.: Schichtaufnahmen in kreisförmiger und anderer nichtlinearer Verwischung. Röntgen Bl. 17 (1964), 197.

BARTELINK, D. L.: Röntgenschnitte. Fortschr. Röntgenstr. 47 (1933), 399.

CZEMBIREK, C.: Neues auf dem Gebiete der Schichtgeräte. Ärztl. Forsch. 16 (1962), 115.

DE WAARD, R. H.: On a fundamental property of planigraphic image formation. Acta radiol. 19 (1938), 165.

EDHOLM, P.: The tomogram. Its formation and content. Acta radiol. (1960) Suppl. No. 193.

GROSSMANN, G. (a): Tomographie I (Röntgenographische Darstellung von Körperschnitten). Fortschr. Röntgenstr. 51 (1935), 61.

— (b): Tomographie II (Theoretisches über Tomographie). Fortschr. Röntgenstr. 51 (1935), 191.

KIEFFER, J.: Analysis of laminagraphic motions and their values. Radiology 33 (1939), 560.

LITTLETON, J. T.: A visual examination of laminagraphic systems. Amer. J. Roentgenol. 91 (1964), 1153.

MATTSSON, O.: *Formation of the tomographic image. With special reference to blurring.* To be published as a Suppl. to Acta radiol.

MORGAN, R. H.: Visual perception in fluoroscopy and radiography. Radiology 86 (1966), 403.

POSCHL, M.: Untersuchungen über das tomographische Bild. I. Teil der Arbeit: Tomographie des Schädels. Fortschr. Röntgenstr. 62 (1940), 33.

STIEVE, F. E.: La technique de radiographie en coupe et les divers modes d'effacement. J. Radiol. Électrol. 38 (1957), 49.

WESTRA, D.: Zonography, the narrow angle tomography. Excerpta Medica Foundation, Amsterdam 1966.

ZIEDSES DES PLANTES, B. G.: Planigraphie. Fortschr. Röntgenstr. 47 (1933), 407.

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Materials and Methods

Biliary excretion. The biliary tropism of B 8890 was compared with that of iopanoic acid in several animal species.

The quota of product excreted with the bile and urine in the first 6 hours following the intravenous administration of a standard dose equivalent to 50 mg of iodinized acid per kg body weight was assessed *in rabbits* and cats, in accordance with a customary screening procedure. These experiments were carried out in animals anesthetized with sodium pentobarbital (25 mg/kg intravenously). Bile was collected through a catheter inserted into the common bile duct and urine drawn off through ureteric catheters.

The biliary excretion of B 8890 and of iopanoic acid was determined during the first 3 hours following the intravenous administration of either compound *for a dosage interval from 20 to 340 μmol/kg in male* Wistar rats weighing between 250 and 300 g, anesthetized with sodium pentobarbital (30 mg/kg intravenously); bile was collected directly from the common bile duct by means of a polythene catheter.

The biliary and urinary excretion of the two compounds in the dog was correlated directly to blood levels. Both B 8890 and iopanoic acid were administered intravenously with a Braun perfusion apparatus at increasing *infusion rates starting with 0.1 μmol/kg/min.* The same *infusion velocity* was maintained for 2 hours. The biliary excretion, urinary excretion, blood concentration, bile flow, and iodine concentration in the bile were recorded every 30 minutes. Bile and urine samples were collected through catheters, from the common bile duct and ureters respectively; blood samples were taken from the common carotid artery half way through each period of bile and urine collection. The data refer to 3 mongrel dogs for each compound: the animals, *weighing between 12 and 15 kg, were anesthetized with chloralose* and urethane and thermoregulated with a heating apparatus governed by a thermal probe lodged in the rectum.

Both products were administered as sodium salts.

Intestinal absorption. The intestinal absorption of B 8890 was compared with that of iopanoic acid and of ipodate in dogs. Six mongrel dogs, weighing between 7 and 9 kg each, were examined in two experiments organized *according to the* 3 × 3 Latin square design: one experiment concerned the dosage level of 50 mg/kg iodinized acid, the other was directed to the dosage level of 100 mg/kg. The compounds were administered by stomach tube in the form of free acid suspended with gum arabic. Each animal received all three compounds in three consecutive doses spaced 7 days apart. The *blood* levels were assessed up to 48 hours after administration in blood samples taken from a peripheral vein.

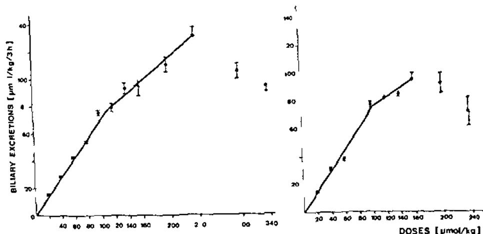


Fig 1 Biliary excretion of various doses of B 8890 (left) and iopanoic acid (right) in the rat The compound was administered intravenously and the bile collected for 3 hours The values are the means of at least four animals the vertical bars represent standard errors

Enterobiliary recirculation The existence of enterobiliary recirculation of B 8890 was investigated in dogs anesthetized with sodium pentobarbital In a first group of animals the biliary and urinary excretion of B 8890 was determined after intraduodenal administration of the compound dissolved in dog bile (0 050 µmol/kg) In a second group the excretion of the compound was determined after intraduodenal administration of the same dose (as iodine) of compound present in the bile excreted by dogs previously treated with B 8890 intravenously The same experiment was repeated with iopanoic acid and ipodate

Protein binding The binding of B 8890 to plasma proteins in the dog was compared by dialysis equilibrium with iopanoic acid and ipodate Two ml samples of plasma containing the contrast media were dialyzed in cellophane tubes against 10 ml of a phosphate Ringer solution at pH 7 2 Dialysis was continued for 6 hours in an agitating bath at 37 C

The equilibrium concentration (A) of the compound under examination was assayed in the dialyzing liquid From the value of (A) and the total amounts of test product and of plasma proteins in the system, r representing the average number of molecules of test product binding each molecule of protein was calculated Protein binding was expressed by relating the value $\frac{r}{(A)}$ to the value r (SCATCHARD 1949)

Table 1

Biliary and urinary excretion The values are the means ± SE

Animal	Compound	Bile* (%)	Urine* (%)
Rabbit	B 8890	34 0±1 9 ($p < 0\ 05$)	19 15±6 83
	Iopanoic acid	22 4±5 0	26 5 ±4 56
Cat	B 8890	52 7±1 3 ($p < 0\ 05$)	3 5 ±2 0
	Iopanoic acid	32 3±4 7	1 9 ±0 1

* Six hours after the administration of 50 mg/kg intravenously as free acid

Assay of test products The test products were assayed by iodine titration with a Technicon P B I autoanalyzer, with which, after destruction of the organic compound, the free iodine was assayed by the Sandell Kolthoff reaction (SANDELL & KOLTHOFF 1934)

Acute toxicity The acute toxicity of B 8890, iopanoic acid, and ipodate was assessed in mice, rats and rabbits treated with the test products administered intravenously and by gavage The Swiss mice and Wistar rats were available from our own nurseries, and the rabbits were obtained commercially All test products were administered, both intravenously and orally, as solutions of the sodium salts The oral toxicity of B 8890 and of iopanoic acid administered in mice in the form of free acids suspended with gum arabic, was also determined LD_{50} values were calculated from mortalities occurring in the first 12 days following treatment, by the method of LITCHFIELD & WILCOXON (1949)

Results

Biliary excretion B 8890 proved more markedly biliitropic than iopanoic acid in nearly all the animal species investigated The amount of B 8890 excreted into the bile was significantly greater than that of iopanoic acid in rabbits and in cats for the time intervals and dosage levels used (Table 1) The quantity of B 8890 excreted into the bile was in rats equal to that of iopanoic acid

Both compounds in the rat are excreted into the bile in about 70 per cent of dose administered for amounts up to a little over 100 μmol/kg (Fig 1), with increasing dosages the percentage excreted into the bile decreased, until

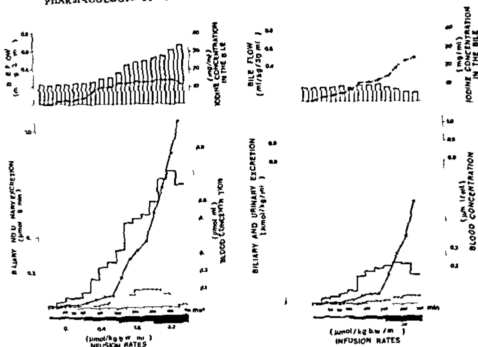


Fig 7 Biliary and urinary excretion of B 8890 (left) and iopanoic acid (*right*) *in the dog* Blood concentrations of the compound with bile flow and iodine concentrations in the bile ——— biliary excretion urinary excretion ●—● blood concentration ⊓ bile flow ×—× iodine concentration in the bile

with the highest doses the reduction of the excretion was absolute This phenomenon which takes place at the level of 240 µmol/kg with B 8890 and 160 µmol/kg with iopanoic acid is almost certainly of toxic nature, since these dosage levels correspond to about a third of the respective LD_{50} values

The data obtained in experiments in dogs appear in Fig 2, biliary excretion reaches a maximum value of 0 23 µmol/kg/min for iopanoic acid and 0 77 µmol/kg/min for B 8890

Immediately above the blood levels corresponding to maximum biliary excretion both compounds produce toxic effects involving the excreting organs namely a reduction in the biliary and urinary excretion of the contrast medium and a reduction in the bile flow The concentration of iodine in the bile reaches 20 mg/ml with iopanoic acid as against 14 mg/ml with B 8890 Iopanoic acid does not increase the bile flow the higher number of molecules of B 8890 transported per unit of time is however associated with a marked increase in the bile flow

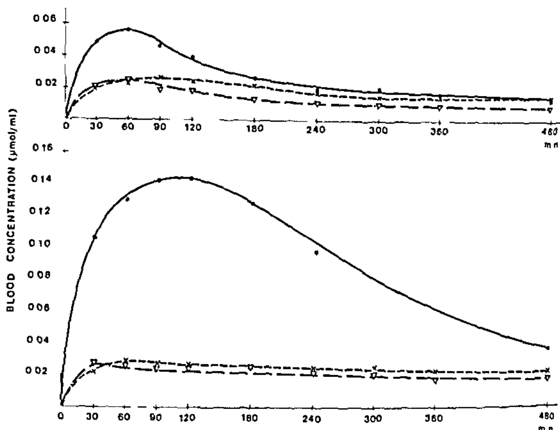


Fig 3 Blood concentrations of the compounds after oral administration of 50 mg/kg body weight (above) and 100 mg/kg body weight (bottom) ●——● B 8890 ×---× ipodate △— —△ iopanoic acid

The urinary excretion compared to the biliary excretion was invariably low with both contrast media

Intestinal absorption B 8890 is absorbed in the intestines more freely than either iopanoic acid or ipodate Experiments with the 3 × 3 Latin square design indicated that the average blood levels obtained with 50 mg/kg B 8890 administered orally were approximately double those obtained with the same amounts of iopanoic acid and ipodate given by the same route (Fig 3, above) The peak levels of B 8890 in dosages of 100 mg/kg were approximately six times those of the reference products, in fact, increased doses of iopanoic acid and ipodate failed to produce blood levels materially higher than those obtained with 50 mg/kg (Fig 3, below)

Enterobiliary recirculation The enterobiliary recirculation of B 8890 was demonstrated by the intraduodenal administration to dogs of samples of bile taken from other dogs previously treated with the test product (Table 2) The

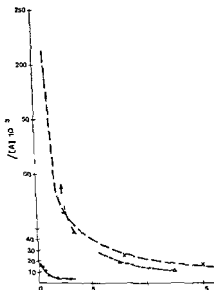


Fig 4 Protein binding of the compounds to dog plasma albumins ●——● B 8890 ×— —× iopanoic acid △———△ ipodate

excretion of iodinized products contained in such samples of bile was 27 per cent through the liver and 8 per cent into the urine

Since the excretion of B 8890 through the liver in the same length of time is 79 per cent it appears reasonable to postulate that the compound is partially transformed into non absorbable metabolites This was recently confirmed by PITRE et coll (1970) who identified all the metabolites of B 8890 both in dogs and human subjects The corresponding data for iopanoic acid and for ipodate also appear in Table 2 the enterobiliary recirculation of both compounds is less than that of B 8890

Plasma protein binding B 8890 has little affinity for plasma proteins in the dog As previously demonstrated by LANG & LASSER (1967) iopanoic acid and ipodate bind at least two classes of sites in plasma protein molecule and have strong affinity for one of these classes On the other hand B 8890 binds only one class of sites for which it has only a weak affinity (Fig 4)

Acute toxicity B 8890 proved significantly less toxic than both iopanoic acid and ipodate based on LD 0 values elicited after intravenous administration The lower value of the ratio of oral LD 0 to intravenous LD 0 confirms that B 8890 is more readily and markedly absorbed in the intestines than the two reference products (Table 3)

It is interesting to note that with oral administration the acute toxicity of B 8890 in the form of an aqueous solution of the sodium salt is the same as

Table 2

Enterobiliary recirculation test Excretion of the compounds (% of dose) after intraduodenal administration mean values ± SE (6 hours after administration) Group I Dogs treated with compounds dissolved in dog bile Group II Dogs treated with compounds excreted with the bile of dogs previously treated intravenously

B 8890			Iopanoic acid			Ipodate		
Bile	Urine	Total	Bile	Urine	Total	Bile	Urine	Total
Group I								
78 9 ± 6 4	8 47 ± 0 95	87 4 ± 6 0	68 8 ± 4 9	2 30 ± 0 84	71 1 ± 4 4	67 0 ± 2 6	2 91 ± 1 21	70 0 ± 3 5
Group II								
27 5 ± 3 0	7 97 ± 0 36	35 5 ± 3 1	20 6 ± 2 6	0 43 ± 0 17	21 0 ± 2 4	17 3 ± 1 2	1 75 ± 0 07	19 0 ± 1 2

Table 3

Acute toxicity LD_{50} (95 % confidence limits) in mg as free acid per kg body weight

Compounds	Mouse	Rat	Rabbit
Oral			
B 8890	1600 (1416—1808)	2860 (2444—3346)	14[illegible]0
Iopanoic Acid	1540 (1294—1986)	2870 (2277—3616)	1380
Ipodate	8[illegible]5 (781—936)	2500 (2137—2925)	
Intravenous			
B 8890	425 (376—480)	445 (393—498)	385 (318—4[illegible])
Iopanoic Acid	285 (250—325)	320 (281—365)	255 (211—308)
Ipodate	240 (212—271)	303 (268—342)	
LD_{50} p o / LD_{50} i v			
B 8890	3 8	6 4	3 7
Iopanoic Acid	[illegible] 4	9 0	6 0
Ipodate	3 6	8 2	—

Table 4

Influence of the administration form upon oral toxicity of B 8890 and iopanoic acid in the mouse LD_{50} (95 % confidence limits) in mg as free acid per kg body weight

Adm form	B 8890	Iopanoic acid
Na solution	1600 (1416—1808)	1540 (1294—1986)
Gum arabic suspension	1950 (1444—2632)	3400 (2266—5100)

that of the product given as free acid suspended with gum arabic The oral toxicity of iopanoic acid as free acid is materially less than of the same product given as an aqueous solution of the sodium salt (Table 4)

Discussion

All experimental findings demonstrate the marked biliary tropism of B 8890, the biliary excretion of the test product is greater than its urinary excretion in all animal species tested The new compound is more markedly biliotropic than iopanoic acid in the cat and the rabbit and equally biliotropic in the rat indeed the percentage of biliary excretion of B 8890 in rats is the same as that of iopanoic acid for dosages of either product sufficiently below the toxic range

The experiments in dogs provide a more complete indication of the kinetic behaviour of B 8890 and iopanoic acid The data in Fig 2 establish that for blood levels up to 0 01 μmol/ml the values of biliary clearance of B 8890 are the same as those of iopanoic acid This means that the two products have equal degrees of biliary tropism On the other hand if biliary tropism be the same, an explanation is required as to why the liver is able to pour iopanoic acid into the bile at a rate not exceeding 0 23 μmol/kg/min, as opposed to 0 77 μmol/kg/min for B 8890

Observations made with cholangiographic contrast media by MILLER et coll (1969) and by ROSATI & SCHIANTARELLI (1970) rather suggest that these values correspond to saturation of the active transport mechanisms effecting the transfer of these compounds from blood to bile In turn the different values of maximum biliary transport (Tm) apparently reflect different degrees of affinity for the same transport mechanism since it is hard to believe that the liver possesses different mechanisms for the excretion of compounds chemically o similar The arrest of the biliary output of iopanoic acid and B 8890 at the levels specified for each product would appear to have nothing to do with the saturation of active transport mechanisms from blood to bile The factor

limiting the biliary excretion of the two contrast media may on the other hand be a toxic factor, and the difference of maximum biliary excretion of the two products may reflect their different degrees of toxicity This hypothesis is supported by the fact that at blood levels slightly higher than those corresponding to maximum biliary excretion, modifications in the liver and kidney occur, that is to say in the biliary and urinary excretion of the compound and reduction in the flow of bile and urine

The true limiting factor in the biliary excretion of orally administered contrast media for cholecystography however in practice is not a matter of toxicity or saturation of liver transport mechanisms, but rather a factor that operates *before the liver, namely intestinal absorption Investigations aiming to define the* extent of intestinal absorption of these compounds in dogs have revealed that the blood levels obtained with dosages of 50 and 100 mg/kg (equivalent to those currently used clinically) fall far short of exhausting the liver's transport capacity At this point, however, B 8890 may set claim to decisive superiority over iopanoic acid and ipodate in that its better intestinal absorption affords a higher output of radio-opaque molecules even though its biliary tropism be no greater than that of the reference products All data available indicate that the average blood levels obtained with 100 mg/kg B 8890 correspond to biliary excretion of 0 25 μmol/kg/min, the same dosage of iopanoic acid on the other hand produces blood levels that correspond to a biliary excretion of only 0 10 μmol/kg/min

Another interesting finding is the low affinity of B 8890 for plasma proteins Opinions differ as to the role of protein binding in biliary excretion LASSER et coll (1962), and LANG & LASSER (1967) believed that a strong binding of plasma albumins is essential for high biliary excretion KNOEFEL (1965) and FISCHER (1965) suggested however that the role of protein binding is only secondary, inasmuch as it prevents the rapid loss of compounds through the renal filter

Recent investigations (ROSATI & SCHIANTARELLI 1970) have revealed high values of biliary clearance for iodinized compounds with a low affinity for plasma proteins, they have also indicated that high protein binding impedes not only the urinary but also the biliary excretion with low serum levels when practically all the molecules of the contrast medium are bound to albumin Since a high capacity for binding plasma proteins is not however a determining factor for the biliary excretion of a contrast medium, it must be regarded as potentially disadvantageous, it may procure undesired effects by altering the binding of important endogenous *substances carried by plasma proteins* The new iodine compound, coded B 8890, presents a number of favourable characteristics suggesting that it represents a significant advance in the field of oral contrast media for cholecystography Such characteristics are biliary tropism better than

(or at least equal to) that of iopanoic acid depending upon the animal species, a lower order of toxicity, improved intestinal absorption and a more consistent enterobiliary recirculation than either iopanoic acid or ipodate its affinity for plasma albumins is low

SUMMARY

A new contrast medium coded B 8890 has proved to be remarkably bilitropic in the rat rabbit cat and dog It has a lower level of acute toxicity better intestinal absorption and a more consistent enterobiliary recirculation than iopanoic acid and ipodate Moreover B 8890 has little affinity for the plasma albumins

ZUSAMMENFASSUNG

Ein neues Kontrastmittel B 8890 bezeichnet erwies sich in der Ratte im Kaninchen in der Katze und im Hund als bemerkenswert bilitrop Es hat eine geringere akute Toxizitat eine bessere intestinale Absorption einen grosseren enterohepatischen Kreislauf als Iopan Saure und Ipodate Ausserdem hat B 8890 eine geringe Affinitat zu den Plasma Albuminen

RÉSUMÉ

Un nouveau moyen de contraste appele en code B 8890 s est montré remarquablement bilitropique chez le rat le lapin le chat et le chien Sa toxicite aigue est moins elevee son resorption intestinale est meilleure et sa recirculation entero biliaire est plus grande que celles de l acide iopanoique et de l ipodate De plus le B 8890 a peu d affinite pour les albumines plasmatiques

REFERENCES

FISCHER H W The excretion of iodipamide Relation of bile and urine outputs to dose Radiology 84 (1965) 483

HOPPE J O The evaluation of odinated organic compounds as radiopaque media J Amer pharm Ass sci Ed 48 (1959) 368

— and ARCHER S Observations on series of aryl triiodo-alkanoic acid derivatives with particular reference to new cholecystographic medium Telepaque Amer J Roentgenol 69 (1953) 630

KNOEFEL P K Radiopaque diagnostic agents Ann Rev Pharmacol 5 (1965) 321

LANG J H and LASSER E C Binding of roentgenographic contrast media to serum albumin Invest Radiol 2 (1967) 396

LASSER E C FARR R S FUJIMAGARI T and TRIPP M The significance of protein binding of contrast media in roentgen diagnosis Amer J Roentgenol 87 (1962) 338

LITCHFIELD J T and WILCOXON F A simplified method of evaluating dose-effect experiments J Pharmacol exp Ther 96 (1949) 99

MILLER G, FUCHS W A und PREISIG R Die Infusionscholangiographie in physiologischer Sicht Schweiz med Wschr 99 (1969), 577

PITRE D e FUMAGALLI L Biotrasformazione dell acido iodoxanico nell uomo (In Italian) Radiol med (Torino) 56 (1970) 836

ROSATI G and SCHIANTARELLI P Biliary excretion of contrast media Invest Radiol 5 (1970) 232

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SCATCHARD G The attraction of proteins for small molecules and ions Ann N Y Acad Sci 51 (1949) 660

ROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR B NORDEN STROM) KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

DIAGNOSIS OF BLOW OUT FRACTURES OF THE ORBIT BY TOMOGRAPHY

by

Mats Haverling

Blow out fractures of the orbit most often affect the floor, omewhat less requently the medial wall or both while the orbital margin remains intact Converse 1962) Smith & Regan (1957) described the pathogenesis which s usually initiated by blunt violence against the eyeball following punches kicks all throwing etc The eyeball is pushed backwards by the blow compressing he contents of the orbit and resulting in a sudden rise of pressure on the latter he weakest part most often the floor is thus fractured and pressed downwards nto the maxillary sinus The eyeball hardly ever suffers appreciable damage or ermanent dysfunction

Blow-out fractures have often been discussed in the literature (Lewin et coll 960 Fueger et coll 1966 Gould & Titus 1966 Milauskas & Fueger 1966 Heller 1970 and others) Despite general agreement that the diagnosis has to be ased on the roentgen examination there is no unanimous opinion as to the nerits of different radiologic methods Thus Fueger et coll proposed the outine use of orbitography as a suitable and reliable method while Gould & Titus propounded the value of tomography Heller did not consider that it is

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a



b



c

Fig 2 Blow-out fracture of the right orbital floor and medial orbital wall a) Orbital floor fracture (→) demonstrated by conventional roentgenography Bleeding into the right maxillary and ethmoidal sinuses b) Tomography discloses no damage of the infra-orbital margin but c) demonstrates fracture of the media orbital wall and revealed the orbital floor fracture

patient prone and only exceptionally in the supine position The orbital floor and the medial wall of the orbit lie vertically with the chin moved forwards o that the central ray is focussed in the midline parallel to a plane through the infra orbital margin and the upper aspect of the external ear (Fig 1) both orbits are thus defined together With the head in position two films are exposed one by the ordinary technique and one by tomography with cycloid movement (Polytome Philips) at a small angle (LINDBLOM 1955), a section through the orbit just posterior to the infra-orbital margin being chosen for this purpose Tangential depiction of the orbital floor is usually obtained although correction of the position with the aid of pilot films is sometimes necessary Following these adjustments in position the orbit is tomographed with ten sections 5 mm apart the first cut running through the infra-orbital margin

The assembled material of pure blow-out fractures diagnosed during 1969 consisted of 3 patients and since the introduction of tomography, a further 10 patients during the last ten months of 1970 All patients had fractures through the orbital floor and in one of them an additional fracture through the medial orbital wall resulting in compression of the ethmoidal sinus (Fig 2)

Conventional roentgenography revealed a fracture of the orbit only in one patient (Fig 2) while it was demonstrated by tomography alone in the other 9

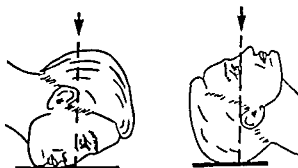


Fig 1 Tomography of the orbital floor The midline central ray is tangential to the orbital floor and a plane through the infra orbital margin and just over the upper margin of the external ear

always necessary to use tomography, but was of the opinion that conventional roentgenography of the facial bones is sufficient, at least in the examination of children

Multiple signs pointing to damage within the orbit are often evident at the clinical examination and include haematoma around or under the eye, diplopia enophthalmos and infra orbital hypoaesthesia or anaesthesia although the signs may sometimes be insignificant or mixed The patient may have noticed double vision early in the acute stage, a symptom sometimes to disappear temporarily but to recur later The reason for these events is that the eyeball which is initially displaced downwards resumes its position in the orbit when the floor is raised again by bleeding, at an even later stage, when the haemorrhage has ceased and the blood is resorbed, the eyeball sinks again into the fracture region If the more or less short period of double vision is interpreted as being caused by contusion of the eyeball rather than by intra orbital fracture, undue delay in treatment may arise and surgical correction become considerably more difficult This is explained by the swiftness with which fibro osseous adhesions are formed within the injured area in the maxillary sinus Operation should therefore be performed at the latest within a week to ten days after the trauma

The necessity of an early diagnosis of blow out fractures has led to the introduction of tomography as an additional aid and mandatory part of the roentgen examination in the acute stage in patients examined for possible injuries of the facial bones Admittedly these wide indications have resulted per se in a large number of patients with a history of facial trauma being examined, but the intention has been not to allow an orbital fracture to remain undiagnosed in the acute stage The injuries received have ranged from insignificant excoriations of the skin to major injuries with clinically demonstrable fractures of the facial bones

Tomography of the orbital floor and the medial orbital wall has always been performed following the conventional roentgen examination on the day of the trauma or at the latest on the next day This is usually carried out with the

i e an average of a patient a month Most injuries were caused by assault Admittedly other types of injuries of the facial bones almost doubled during the same period but the number of patients with pure blow out fractures more than trebled The cause of this may naturally depend on an actual increase in the number of injured persons in this group but may also be due to the improved examination technique introduced in the beginning of 1970 It was thus possible to demonstrate that the mucous membrane changes in the roof of the maxillary sinus observed by the ordinary roentgen technique and often demonstrated in facial injuries is associated with blow out fractures of the orbit (Fig 3)

The ordinary late complications in blow-out fractures are difficulty in moving the eyeball and double vision Early surgical intervention is necessary in view of the swiftness with which fibro-osseous adhesions are formed in this region The generous attitude towards early examination by means of tomography, has meant that most interventions in this group could be carried out on the day following the trauma and at the latest on the fourth day by simple Caldwell Luc or orbitotomy procedures Operation at a later stage would be considerably more difficult with plastic repairs and the insertion of bone transplants into the orbital floor for elevation of the eyeball

SUMMARY

Routine tomographic examination of the facial bones is a valuable diagnostic aid and provides early diagnosis of the otherwise easily overlooked blow-out fracture of the orbital floor or medial wall Urgent examination is necessary since operation if to remain simple should be undertaken not later than ten days following the trauma Ten patients are reviewed

ZUSAMMENFASSUNG

Routine Tomographie Untersuchungen des Ansichtskeletts sind ein wertvolles diagnostiches Mittel und ermoglichen die fruhzeitige Diagnose der sonst leicht zu ubersehenden Ausblasfraktur des Orbitalgrunds oder der medialen Wand Eine dringende Untersuchung ist notwendig da eine Operation sofern diese einfach bleiben soll nicht spater als zehn Tage nach dem Trauma vorgenommen werden sollte Zehn Patienten werden zusammenfassend beschrieben

RÉSUMÉ

L examen tomographique systématique du squelette facial est un bon moyen de diagnostic et contribue au diagnostic precoce des fractures par enfoncement du plancher de l orbite ou de sa paroi interne fractures qui sans cet examen passent facilement inaperçues Il est necessaire de faire cet examen en urgence car pour que l operation reste simple elle doit etre faite moins de 10 jours apres le traumatisme L auteur présente dix cas

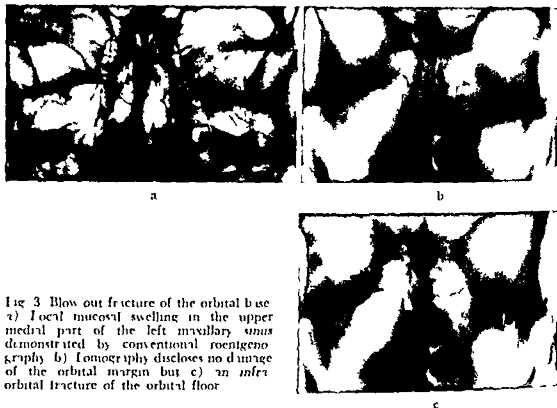


Fig. 3. Blow out fracture of the orbital base. a) Local mucosal swelling in the upper medial part of the left maxillary sinus demonstrated by conventional roentgenography. b) Tomography discloses no damage of the orbital margin but c) an infraorbital fracture of the orbital floor.

patients (Fig. 3). The ordinary roentgen technique disclosed mucous membrane thickening in the roof of the adjacent maxillary sinus caused by submucosal bleeding in all 10 patients. This embraced the entire roof or part of it and was localized and polyp-like. Fluid suggesting blood usually lay in in the maxillary sinus on the injured side.

The fracture was first demonstrated in 9 patients by tomography so that the extent of the injury could be evaluated only after this examination. The displacement of the bone fragments downwards in the maxillary sinus in all 10 patients was from 2 to 8 mm, the breadth and depth of the fracture area varying between 1 and 1.5 and 1 and 2 cm respectively.

Discussion

The number of patients referred with injuries of the facial bones rose markedly during 1970 as compared to 1969. The reason was partly due to the increase in both road traffic accidents and the use of physical violence. Thus, while during 1969 only 3 patients with pure blow out fractures were examined, those with this type of injury increased to 10 during a ten month period of 1970,

FROM THE THIRD MEDICAL CLINIC (DIRECTOR PROF V PACOVSKY), CHARLES UNIVERSITY PRAGUE CZECHOSLOVAKIA

SOFT TISSUE RADIOGRAPHY OF THE FEMALE BREAST AND PELVIC PNEUMOPERITONEUM IN THE STEIN LEVENTHAL SYNDROME

by

V PALCAR EVA SILINKOVA MALKOVA and Z MATYS

The syndrome of polycystic ovaries and varying combinations of irregular menstruation sterility hirsutism and obesity is usually considered rare Nevertheless the Stein—Leventhal syndrome continues to attract the attention of specialists and is not infrequent in hospitals dealing with endocrinopathies The results of surgery are usually excellent The importance of early diagnosis is stressed by the fact that the patients are young women in whom the frequent and increasing hirsutism and obesity usually add to the psychic disturbances the preoperative diagnosis is helped by the reliability of pelvic pneumoperitoneum

A decreased production of oestrogens results in increased amounts of precursors of an androgen nature This change in steroids is not sufficient to produce frank virilization but in 94 per cent of patients results in hirsutism and in 67 per cent in significant changes in vaginal smears (MATYS et coll 1968) Previous experience with soft tissue radiography of the female breast in endocrinopathies drew attention to the mammary gland which in function and evolution is dependent on hormonal regulation It would appear that radiography of the

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REFERENCES

CONVERSE J M Blowout fracture of the orbit *Plast reconstr Surg* 29 (1962) 408

CRAMER L, TOOZE F and LERMAN S Blowout fractures of the orbit Brit J plast Surg 18 (1965), 171

DEVOE A Fractures of the orbital floor Arch Ophthal 39 (1948) 595

FUEGER G F, MILAUSKAS A T and BRITTON W W Roentgenologic evaluation of orbital blowout injuries Amer J Roentgenol 97 (1966), 614

GOULD H R and TITUS C O Internal orbital fractures The value of laminagraphy in diagnosis Amer J Roentgenol 97 (1966) 618

HELLER R M The clinical and radiological presentation of blowout fracture of the orbit in children Pediatrics 46 (1970), 796

LEWIN J R RHODES JR D H and PAVSEK E J Roentgenologic manifestations of fracture of orbital floor (blowout fracture) Amer J Roentgenol 83 (1960), 628

LINDBLOM K Rotation tomography at small angles Acta radiol 43 (1955), 30

MILAUSKAS A T and FUEGER G F Serious ocular complications associated with blowout fractures of the orbit Amer J Ophthal 62 (1966) 670

SMITH B and REGAN W F Blowout fractures of the orbit Amer J Ophthal 44 (1957), 733

SUTTON D A textbook of radiology E & S Livingstone Ltd Edinburgh and London 1969

WILDER L R Blowout fractures of the orbit Penn med J 71 (1968), 37

ZIZMOR J, SMITH B FASANO C and CONVERSE J M Roentgen diagnosis of blowout fracture of the orbit Amer J Roentgenol 87 (1962) 1009

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Table 1

Patients examined by soft tissue radiography of the female breast and pelvic pneumoperitoneum

Findings	No. of patients
Normal	23
Stein-Leventhal syndrome	61
Confirmed by surgery in 34	
After surgery (cured)	7
Total	91

female breast has not been used so far in the investigation of the Stein—Leventhal syndrome. Some authors (STEIN 1958, LEVENTHAL & SCOMMEGNA 1963) have described small breasts as typical in this disease although large breasts have been reported (JANATA & STAVKA 1967, DECOURT et coll. 1962). The size of the breasts is of course dependent on the amount of fatty tissue and does not directly correspond with the amount of gland. Soft tissue radiography was therefore selected as a method yielding reliable and objective information on the evolution of the gland; patients with menstrual irregularity or amenorrhoea or a likely Stein—Leventhal syndrome formed the material examined.

Material and Methods. The results of pelvic pneumoperitoneum and soft tissue radiography of the female breast were compared in 61 patients with the Stein—Leventhal syndrome. The diagnosis was confirmed by surgery and histology in 34 patients (Table 1) and in the remaining 27 patients was based on radiologic, clinical and biochemical findings. The age of the patients ranged from 16 to 32 with an average of 22.9 years, this means that the group was homogeneous as far as the age was concerned.

Pelvic pneumoperitoneum was described by PETERSON (1921) and has been modified only by the amount of gas insufflated and the positioning of the patient (BETOULIERES et coll. 1955, RADBERG & WICKBOM 1967, VALLEBONA & DOCLIOTTI 1937). The present authors introduce 600 to 700 ml CO_2 transparietally and intraperitoneally and obtain roentgenograms in the genupectoral or modified Trendelenburg positions under fluoroscopic control (ŠILINKOVÁ-MALKOVÁ 1961, 1963, ŠILINKOVÁ-MALKOVÁ & MATIS 1966). The appearances are fairly uniform: 25 per cent of patients have a normal uterus which in the remainder is small or hypoplastic. The ovaries are more or less enlarged with distinct or slightly polycyclic contours but because of the variability caused by distortion the size



Fig 1



Fig 2

Fig 1 Normal mammary gland Juvenile typ Almost homogeneous triangular gland surrounded by thin layer of subcutaneous fat

Fig 2 Slightly more inhomogeneous gland Fertility type

of the organs is ignored The radiography of the female breast is performed with a low 35 to 40 kV 600 to 800 mAs and conventional films without intensifying screens The mediolateral projection was sufficient for the purpose of the investigation The evaluation of the films was made in correlation with findings in normal women of given ages as the hormonal stimulation of the mammary gland during fertile life varies with age Appearances normal in a relatively old patient may reflect insufficient hormonal stimulation in a young woman The correlation of normal radiographic appearances of the breast with age was effected from previous results of pelvic pneumoperitoneum in 256 women of various age groups examined for cancerophobia (Balcar et coll 1967 Papez et coll 1968) An



Fig. 3. A 22-year-old woman with the Stein—Leventhal syndrome: obesity, hirsutism, enlarged ovaries and a small uterus

investigation of 23 women with congenital changes without any hormonal disorder by means of pelvic pneumoperitoneum and soft tissue radiography of the breast also acted as controls. Seven with the Stein—Leventhal syndrome following surgery for sterility and who had had the latter examination performed were added. The material is summarized in Table 1, the 256 women previously investigated with radiography of the breast are excluded.

The evaluation of soft tissue radiography of the breast is based on the principle that the evolution of the gland corresponds to an outline while the involution is characterized by the prevalence of fat with fibrous supporting tissue. The age homogeneity of the present material requires only two physiologic types for comparison.

(1) A juvenile type in which practically the whole breast is occupied by homogeneous glandular tissue, triangular in shape, covered by only a thin layer of subcutaneous fat (Fig. 1). This type is most frequent at 20 years of age.

(2) A fertility type with nearly the same ratio of nodular glandular tissue and transparent areas corresponding to a balanced hormonal stimulation of the gland. This type is most frequent in women of about 25 years (Fig. 2).

A decrease in the glandular tissue, i.e. where the gland looks older, appears to be evidence of a hormonal disorder. This was evident in 87 per cent of the patients, who have been divided into three groups with marked (XXX), moderate (XX), and nearly normal or normal (X) findings; the results of pelvic pneumoperitoneum have been divided in a similar way for comparison.

The patients were divided into five further groups. Groups 1 to 4 are summarized together in Table 2 while group 5 appears separately in Table 3 because of the uniform appearances of glandular hypoplasia with small breasts.



Fig 4

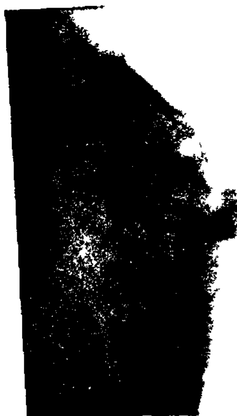


Fig 5

Fig 4 Same patient as in fig 3 Marked reduction in glandular parenchyma with prevalence of fatty tissue and only few areas of supporting tissue

Fig 5 A 21 year old woman with hirsutism and some obesity with similar reduction in glandular parenchyma as in the Stein—Leventhal syndrome in fig 4 Pelvic pneumoperitoneum nearly normal

(1) The largest group of 22 patients was characterized by complete agreement in the findings of the two methods (Figs 3 4) The appearances were well defined in both methods in 19 patients and were typical in 3 patients Sixteen patients had breasts of normal size and evidence only in the roentgenograms of glandular atrophy

(2) Soft tissue radiography of the breast in all 16 patients presented evidence of marked decrease in the glandular parenchyma the size of the breasts being slightly diminished in 10 patients The findings obtained with pelvic pneumoperitoneum were marked in 7 patients moderate in 8 and nearly normal in 1 patient

Table 2

Correlation of radiologic and clinical findings

Group	No. of patients	Mean age	Obesity	Hirsutism	Breasts		Soft tissue radiography of the female breast			Pelvic pneumoperitoneum		
					Normal	Small	*	**	***	*	**	***
1	22	23.1	18	16	16	6	—	3	19	—	3	19
2	16	23.7	8	10	6	10	—	16	—	1	8	7
3	6	23.5	5	5	—	6	—	—	6	6	—	—
4	8	21.4	1	5	—	8	8	—	—	—	2	6
Total	52		32	36	22	30	8	19	25	7	13	32
Per cent			62	71	42	58	13	31	56	13	23	64

(3) This group consisted of 6 women, mostly with hirsutism and obesity and normal or nearly normal pelvic pneumoperitoneum, while radiography of the breast presented typical evidence of a hormonal disorder (Fig. 5).

(4) Eight patients had a normal pelvic pneumoperitoneum but the radiography of the breast yielded false negative results. Only one woman was obese (Table 2).

(5) The uniform radiographic appearances of combined hypoplasia of the gland and breast was the characteristic feature of this group, the findings obtained at pelvic pneumoperitoneum being distinct in 7 patients, typical in 1 and normal in 1 patient (Fig. 6). The clinical and radiologic findings are summarized in Table 3.

Patients fertile after surgery. The radiographic appearances of the breast of 7 patients in whom sterility was treated by wedge resection of the ovaries were checked. It is interesting that even these patients, who later had a normal pregnancy had similar poor development of the gland as most of the patients mentioned (Fig. 7). This group was however excluded from the statistics as it consisted mostly of women over 30, in whom the gland may normally be diminished.

Discussion

The evaluation of pelvic pneumoperitoneum and soft tissue radiography of the female breast is, especially as far as division into various groups is concerned, somewhat arbitrary. Typical appearances in which immediate classification was possible have been mixed with uncertain signs especially in normal or nearly nor

Table 3

Correlation of radiologic and clinical findings

Group	No of patients	Mean age	Obesity	Hirsutism	Breasts		Soft tissue radiography of the female breast			Pelvic pneumoperitoneum		
					Normal	Small	*	**	***	*	**	***
5	9	21 8	2	5	—	9	—	—	9	1	1	7

Findings
* Normal or nearly normal
** Moderate
*** Marked

mal patients The films were reviewed three times without knowledge of the clinical aspects the results of surgery or, of course the previous roentgen evaluation

Soft tissue radiography of the breast in the first two groups confirmed the diagnosis of a hormonal disorder and *may in such cases serve as an easy and* simple screening test before a more complicated investigation The results in the third group were interesting The pelvic pneumoperitoneum was nearly normal *in all* patients with abnormal findings of the breast in the final radiologic evaluation The opposite was evident in the fourth group Pelvic pneumoperitoneum demonstrated in all 8 women features indicating the Stein—Leventhal syndrome while the breast examination was nearly normal or normal The fifth group with combined hypoplasia of not only the gland but also of the whole breast had signs different from those originally described for the syndrome and which occurred soon after the menarche This explains the underdevelopment of both the gland and the breasts Hypophyseal stimulation of the gonads is *contrary to the normal cycle* type in women of the reproductive age but monophasic in the Stein—Leventhal syndrome This atypical stimulation results in some similarity of the genesis of steroids in the ovaries to that in testicular tissue even in the pattern of steroids in a biochemical assay (JANATA & STARKA 1967 SHEARMAN & COX 1965) The disorder is not sufficient to result in virilization but certain minor signs such as hirsutism *changes* in vaginal smears and variation in the amount and ratio of urinary steroids may occur (DECOURT et coll 1962)

The discrepancy in the description of the breasts by various authors has already been mentioned Contrary to the original description large breasts may



Fig. 6



Fig. 7

Fig. 6. Stein—Leventhal syndrome in a 17-year-old girl with progressive hirsutism but no obesity. Onset of menstrual irregularity at 15 years. Reduction of the gland in combination with hypoplasia of the whole breast.

Fig. 7. A 31-year-old patient with obesity and hirsutism 5 years after wedge resection of both ovaries and 2 years after delivery. Still poor development of the entire gland with large breasts and prevalence of fatty tissue.

occur in patients with the Stein—Leventhal syndrome. GOLDZIEHER & AXELROD (1963) tried to explain this by suggesting that the ovaries react in the early stages of the disease with the higher production of oestrogens. The ratio of fatty and glandular tissue cannot however be judged only by clinical examination. The supposed hypertrophy may sometimes be due only to vicarious fatty tissue accompanied by decrease in the actual gland.

SUMMARY

The results of soft tissue radiography of the female breast and pelvic pneumoperitoneum in 61 patients with the Stein—Leventhal syndrome are presented. Radiography of the breast will demonstrate a decrease in the glandular parenchyma even where large breasts with

much fatty tissue simulate hypertrophy It may also serve to reveal a hormonal disorder before a more complicated and precise investigation Radiography of the breast may facilitate the final diagnosis where the appearances of pelvic penumoperitoneum are normal or nearly normal

ZUSAMMENFASSUNG

Die Ergebnisse der Weich Gewebe Radiographie der weiblichen Brust und des Becken pneumoperitoneums bei 61 Patienten mit einem Stein—Leventhalschen Syndrom werden vorgelegt Untersuchung der Brust lasst eine Verminderung des Drusen Parenchyms auch bei grossen Brusten bei denen viel Fettgewebe eine Hypertrophie vortauschen erkennen Sie mag auch dazu dienen eine hormonelle Storung vor einer mehr komplizierten und genaueren Untersuchung zu zeigen Rontgenuntersuchung der Brust mag die schliessliche Diagnose erleichtern wenn das Bild des Becken pneumoperitoneums normal od r an nahernd normal ist

RÉSUMÉ

Les auteurs presentent les résultats de la radiographie de parties molles du sein d la femme et du pneumoperitoine pelvien chez 61 malades atteintes de syndrome de Stein Leventhal L examen du sein montre habituellement une diminution du parenchyme glan dulaire meme dans les cas ou des seins volumineux contenant beaucoup de tissu adipeux simul nt une hypertrophie L examen du sein peut aussi servir pour deceler un trouble hormonal avant de faire des examens plus compliques et plus precis L examen radio graphique du sein peut faciliter le diagnostic final dans les cas ou le pneumoperitoine pel vien donne des images normales ou presque normales

REFERENCES

BALCAR V PAPEŽ L und FABIÁNOVA J Die Auswertung der Mammographie vom Ge sichtspunkt der Entwicklung und Involution der Milchdruse Anthropologie (Brno) 5 (1967) 21

BETOULIERES P PELESSIER M BERTRANDO L et coll Stratigraphie et agrandissement en pneumographie pelvienne chez la femme J Radiol Electrol 36 (1955) 94

DECOURT L JAYLE M et MAUVAIS-JARVIS P Syndrome de Stein Leventhal et virilisme pilaire Presse méd 70 (1962) 365

GOLDZIEHER J and AXELROD L Clinical and biochemical features of polycystic ovarian d seas Fertil and Steril 14 (1963) 631

JANATA J a STÁRKA L *Virilisačni syndromy* SZD Praha 1967

LEVENTHAL M and SCOMMEGNA A Multiglandular aspects of the Stein Leventhal syndrome Amer J Obstet Cynec 87 (1963) 445

MATYS Z ŠILINKOVÁ MÁLKOVÁ E VRBOVÁ H et coll K diagnoze Steinova Leventhalova syndromu I část kl nicka (In Czech) Sborn lék 70 (1968) 160

PAPEŽ L ALJEZDÇKY Z BALCAR V und FABIÁNOVÁ L Die Auswertung der Mammographie vom Gesichtspunkt der Entwicklung der Reproduktions Organe Zbl Gynak 90 (1968 703

PETERSON R The x ray after the inflation of the pelvic cavity with carbon dioxide gas as an aid in obstetric and gynecologic diagnosis Surg Gynec Obstet 33 (1921) 154

RADBERG C and WICKBOM I Pelvic angiography and pneumoperitoneum in the diagnosis of gynecologic lesions Acta radiol Diagnosis 6 (1967) 133

SHEARMAN R and COX R Clinical and chemical correlations in the Stein Leventhal syndrome Amer J Obstet Gynec 92 (1965) 747

STEIN I The Stein—Leventhal syndrome Clin Obstet Gynec 2 (1958), 207

ŠILINKOVA MALKOVÁ E Pneumopelvigraphy in diagnosis of gonadal lesions in women Radiol diagn (Berl) 2 (1961) 61

— Rentgenová diagnostika syndromu Steinova Leventhalova Acta Univ Carol Med (Praha) (1963) Suppl No 17, p 167

— and MÁLEK J Roentgenological approach to the problems of virilisation Excerpta Medica Amsterdam 1966

VALLEBONA A e DOGLIOTTI V Contributo alla esplorazione radiologica dell apparato genitale femminile Ann di Radiol e Fis med 11 (1937) 126

FROM THE ROENTGEN DEPARTMENT (DIRECTOR BROR BRODÉN), ST GORANS SJUKHUS STOCKHOLM, SWEDEN

CHOLECYSTOKININ PANCREOZYMIN IN CELIAC AND SUPERIOR MESENTERIC ANGIOGRAPHY

by

ROLF UDÉN

Pancreatic angiographies are usually performed with the pancreas at rest Inactivity implies low oxygen consumption and is associated with a low blood flow Secretin increases the blood flow rate through the pancreas as well as the width of the pancreatic vessels o that more contrast medium may be injected during a shorter time and produce a more accurate investigation (UDÉN 1969)

Cholecystokinin pancreozymin acts as a catalyst in the production of enzymes in the pancreas and differs from secretin which is particularly concerned in the production of sodium bicarbonate and water The preparation probably increases the oxygen consumption in the pancreas associated with an increased blood flow Cholecystokinin pancreozymin accelerates peristalsis in the duodenum jejunum and ileum leading to a decreased transit time through the small intestine (DAHLGREN 1964) the effect on the small bowel may be inhibited by atropine (HEDNER et coll 1967) Furthermore a contraction of the gallbladder is elicited by cholecystokinin pancreozymin an increased flow of bile from the liver is obtained and the flow resistance of the choledochoduodenal junction is reduced (BRODÉN 1958 JORPES & MUTT 1966 JONSON et coll 1964)

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The effect of the preparation on the small muscles of the gallbladder is not inhibited by atropine (HEDNER et coll 1967) The preparation employed contained about 10 per cent secretin as impurity Angiography after its administration has apparently not previously been performed

The present investigation was carried out during the period 1967—1969 to ascertain its effect on the vessels during angiography of the pancreas and whether it would assist in the diagnosis

Material This consisted of 20 patients aged between 34 and 75 with a mean of about 55 years and made up of 16 men and 4 women The patients were examined for probable carcinoma of the pancreas or to investigate the circulation in portal hypertension often because of cirrhosis of the liver The diagnoses were based on angiography, clinical examinations, operation or autopsy Eight patients had cirrhosis and 3 hepatic insufficiency indicated by laboratory investigations Seven of these 11 patients had portal hypertension, and 2 in addition gallstones with changes in the wall of the gallbladder One patient suffered from subacute pancreatitis with abscess formation and one had choledocholithiasis One patient had carcinoma of the pancreas and one with carcinoma of the duodenum had undergone cholecystectomy Several patients were chronic alcoholics, especially among those with cirrhosis Five patients were free from disease

Methods

Angiographic examination technique and the administration of cholecystokinin pancreozymin Selective angiographies were performed with MIKAELSSON (1965) catheters inserted after puncture of the femoral artery Combined celiac and superior mesenteric angiography was carried out in 17 patients and celiac angiographies alone in 3 patients The catheters were Y coupled in the former and for each angiography 50 ml Urografin 76 % or Isopaque Coronar were injected with automatic equalization at 4 kg atmospheric pressure

The film series were made to a standardized program with films as follows 2/s for 4 s, 1/s for 3 s and 1/s every third second for 15 s, each series thus continued for 20 seconds The first angiographic series was always performed without drugs A series with secretin was obtained in 9 patients followed by a series with cholecystokinin pancreozymin The series with cholecystokinin pancreozymin was in 11 patients carried out 20 min after the series without drugs, 150 Ivy units of the preparation were injected through the catheters, half in each, 45 to 120 s before the administration of the contrast medium The series were performed under identical conditions as regards injection pressure, type and amount of contrast medium, exposure data and film series The series with chole

cystokinin pancreozymin were usually obtained in a right posterior projection The circulation through the gallbladder liver small intestine and pancreas was recorded

Recording of the vessels The volume of the arteries was estimated by measuring the diameter of the gastroduodenal artery, the left or right hepatic artery, the cystic artery and a main branch of the superior mesenteric artery supplying the small intestine The diameter of the gastroduodenal artery was recorded 1 cm from its origin the measurements being made in the first roentgenograms in which filling of a mall pancreatic artery was obtained in each series the diameters of the other arteries were determined from the same film

The number and width of the small pancreatic arteries and the accumulation of contrast medium in the pancreas during the capillary phase — pancreatographic effect — were estimated and classified in degrees of 1 to 4 from small to large and u ed as parameters for the capillary phase The accumulation of contrast medium in the wall of the gallbladder during capillary phase was like wi e estimated and classified The width of the peripheral liver arteries (less than 1 mm in diameter) was al o estimated and compared

The diameter of the portal vein was measured to determine the volume of the veins The measurements were made in the film in which the portal vein was best ob erved The visibility was al o estimated and classified in degrees of 1 to 4 and compared between the series The absorption of the roentgen rays in a ves el i e its visibility in the film is in direct proportion to its width and the concentration of contrast medium which in its turn depends on the amount injected per unit of time and the blood flow rate

Recording of the rate of blood flow Two films per second were obtained during the first 4 seconds The pressure injector was so adjusted that the fir t and second films were obtained without contrast medium for subtraction The third film could then be fully exposed at the earliest half a second after start of the injection The ab olute time is of less interest than the difference in time in a comparison of blood flow rates *in two* eries performed in exactly the same way The third film was considered exposed half a second after the start of the injection The time elapsing from start of the *injection* to the appearance of contrast medium in a mall artery (diameter under 1 mm) is called the arterial filling phase (GREITZ 1956) and was determined in the liver, gallbladder pancreas and small intestine The time from the start of the injection to the disappearance of contrast medium from the arteries is called the arterial phase and was recorded in the same areas this depends on the length of the injection As the injection pressure was not altered between the series the time was con tant The time required for maximal accumulation of contrast medium in the

Table 1

Effect of cholecystokinin pancreozymin on the gallbladder circulation in thirteen combined celiac and superior mesenteric angiographies and three celiac angiographies. Mean values (range values in parenthesis)

	Without preparation	With preparation
Diameter of the cystic artery (mm)	1.1 (0.5—1.5)	1.9 (1.5—3)
Arterial filling phase of the cystic artery (seconds)	1.9 (1.5—3)	1.3 (1—2)
Time (seconds) after start of contrast injection for maximal accumulation of contrast medium in gallbladder wall	9 (9)	5.2 (3—8)

wall of the gallbladder was recorded. The times necessary for the first appearance of contrast medium in the portal vein and for the maximal filling of this vein were also registered.

Recording of reflux. Reflux to the aorta from the celiac and the superior mesenteric artery was noted, its degree was estimated and classified from slight to large, i.e. from 1 to 4.

Results

Gallbladder circulation. The cystic artery was filled in 16 of the 20 patients, the effect of cholecystokinin pancreozymin on the gallbladder circulation in these patients was analysed. *The blood flow through the gallbladder increased after its* administration in 15 patients. The diameter of the cystic artery increased in mean from 1.1 mm to 1.9 mm. The mean of the arterial filling phase of the cystic artery shortened from 1.9 s to 1.3 s (Table 1, Fig. 1). The accumulation of contrast medium in the wall of the gallbladder increased after cholecystokinin pancreozymin. The gallbladder was not demonstrable in 14 patients without it and when administered the amount of contrast medium within the wall was great in 8 patients, moderate in 5 and slight in one patient. The gallbladder was in one patient slightly outlined after 9 s, without it, and maximally visible after 6 s, with it (Fig. 2). Maximal amount of contrast medium within the gall bladder wall was observed in a mean 5.2 s after the start of the injection (Table 1). The cystic vein or the choledochal vein (PETREN 1933) was *demonstrable* with injection of the extract in 5 patients but never without (Figs. 2, 4). The sixteenth patient had chronic cholecystitis with a thickened and fibrotic wall and



Fig 1 Normal combined celiac and superior mesenteric angiography both films exposed 10 s after the start of injection of contrast medium a) Without and b) with 75 Ivy units of cholecystokinin pancreozymin injected into the arteries 2 min before the former The peripheral intrahepatic arteries decreased in width and were later filled the cystic artery increased in width (→) and was earlier filled

no effect of cholecystokinin pancreozymin was recorded, the cystic artery was identified but neither the width nor the arterial filling phase were altered The circulation of the gallbladder could not be analysed in 4 patients because neither the cystic artery nor the wall of the gallbladder could be identified One patient had undergone cholecystectomy and 2 had advanced cirrhosis with portal hypertension and oesophageal varices the fourth had chronic cholecystitis

Hepatic circulation The central arteries in the liver increased in width in 15 of 20 patients in the others the diameter did not alter The mean diameter of the left or the right hepatic artery increased from 4 3 mm to 5 1 mm after cholecystokinin pancreozymin (Table 2) but the width of the peripheral hepatic arteries decreased The diameter diminished in 16 of 20 patients and in 4 the diameter failed to alter The arterial phase was long in one patient, i e 9 s and

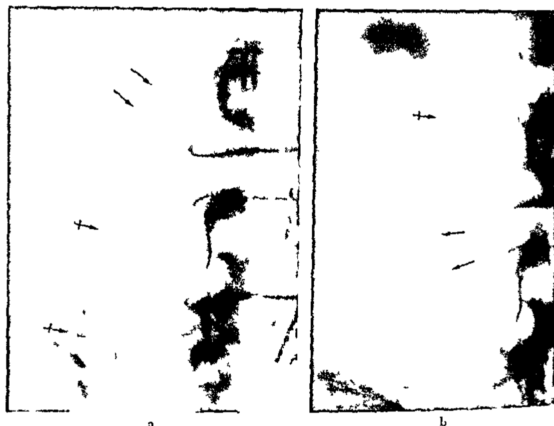


Fig. 2. Same case as in fig. 1. Both films with cholecystokinin-pancreozymin. a) 7.5 s and b) 14 s after start of injection of contrast medium. a) Late capillary phase. Wall of the gall bladder (→→) commencing filling of the cystic vein (→). b) Venous phase. Filling also of choledochal vein (→) with contrast medium remaining in the proximal part of the cystic vein (→→). The choledochal vein anastomoses with the intestinal veins, usually the pancreatico-duodenal vein or directly with the portal vein.

did not alter after cholecystokinin-pancreozymin. The patient suffered from severe portal hypertension and was excluded from the investigation of the circulation time. The arterial filling phase of the liver was prolonged after administration of the preparation, the mean of the filling phase increased from 1.3 s to 2.0 s and the arterial phase from 3.8 s to 5.4 s (Table 2, Fig. 1). The time from the start of the injection to maximal outlining of the portal vein did not alter between the series without and with cholecystokinin-pancreozymin, but the width of the portal vein increased. The mean diameter increased from 15.6 mm to 18.0 mm and the visibility increased in relation to the widening of the vein (Fig. 4).

The circulation in the small intestine. Combined celiac and superior mesenteric angiographies were performed in 17 patients and the effect of cholecystokinin-pancreozymin on the mesenteric vessels was analysed. The width of the

Table 2

Effect of cholecystokinin pancreozymin on the hepatic circulation in sixteen combined celiac and superior mesenteric angiographies and three celiac angiographies Mean values (range values in parenthesis)

	Without preparation	With preparation
Diameter of the left or the right hepatic artery (mm)	4 3 (2 5—6)	5 1 (3—7)
Arterial filling phase (seconds)	1 3 (1—2)	2 (1 5—3 5)
Arterial phase (seconds)	3 8 (1 5—6)	5 4 (3 5—9)

Table 3

Effect of cholecystokinin pancreozymin on the circulation of the small intestine in sixteen combined celiac and superior mesenteric angiographies Mean values (range values in parenthesis)

	Without preparation	With preparation
Diameter of a main branch of the superior mesenteric artery supplying the small intestine (mm)	3 1 (2—5)	3 7 (2 5—5)
Arterial filling phase (seconds)	1 5 (1—2)	1 0 (0 5—1 5)
Arterial phase (seconds)	5 2 (3 5—9)	4 0 (2 5—6)

vessels supplying the duodenum jejunum and ileum generally increased The mean diameter of a main branch of the superior mesenteric artery supplying the small intestine increased from 3 1 mm to 3 7 mm (Table 3 Fig 3) The blood flow rate through the small intestine increased after the administration of the preparation The mean arterial filling phase decreased from 1 5 s to 1 0 s and the arterial phase from 5 2 s to 4 0 s (Table 3)

A patient with a long hepatic circulation time also had a long circulation time in the small intestine after cholecystokinin pancreozymin and was excluded

Pancreas circulation The effect of cholecystokinin pancreozymin on the pancreas circulation was the same as after secretin stimulation (UDEN 1969) although less marked Both the width of the vessels and the blood flow rate increased

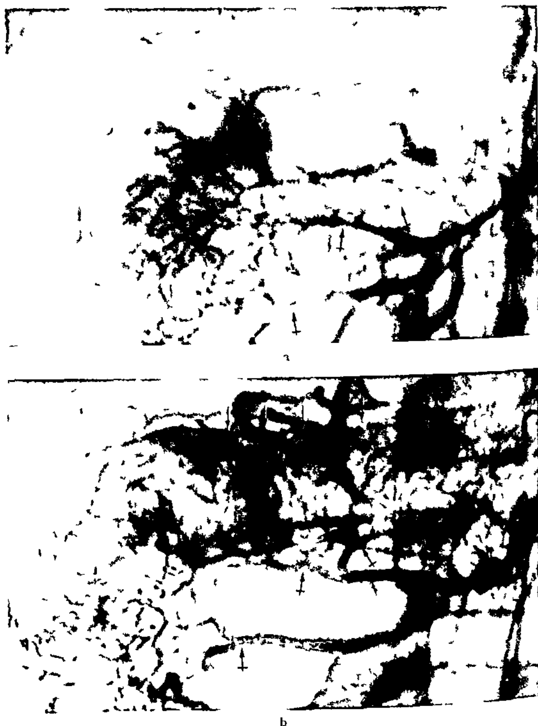


Fig. 3. Normal combined celiac and superior mesenteric angiography, both films exposed ?0 s after the start of injection of contrast medium, a) without and b) with 75 Ivy units of cholecystokinin-pancreozymin injected into the arteries 1.5 min before the former. The branches of the superior mesenteric artery supplying the small bowel were wider (↔) and the visibility of the vessels increased after the preparation. An increased number of peripheral arteries were filled and the wall of the bowel was faintly outlined (→).



Fig. 4. Normal combined celiac and superior mesenteric angiography, both films exposed 12 s after start of injection of contrast medium a) without and b) with 75 Ivy units of cholecystokinin pancreozymin injected into the arteries 2 min before the injection of the former. Both films represent maximal visibility of the portal vein obtained at the *same time*, but the portal and splenic veins were wider *after the* preparation (⟷). b) Filling of choledochal vein (⟶).

Reflux Reflux to the aorta was not significantly influenced and in 11 patients was equally large in both series The reflux diminished in 7 and increased in 2 patients The difference between the series was only slight

Discussion

Gallbladder Cholecystokinin pancreozymin produces contraction of the gall bladder This activity implies a higher oxygen consumption and is associated with an increase in blood flow The width of the cystic artery increased and the arterial filling phase shortened Since a larger amount of contrast medium can be supplied to the gallbladder in a shorter time after the administration of the preparation, a better filling of the capillaries was obtained resulting in a greater amount of contrast medium within the wall of the gallbladder Better filling of the veins was obtained and the cystic vein and the choledochal vein could be identified (Fig 2) No effect of the preparation could be recorded in 2 patients suffering from chronic cholecystitis A gallbladder with a fibrotic and thickened wall cannot be presumed to act normally, so that failure of response to the preparation is not remarkable

Liver Contraction of the peripheral hepatic arteries was obtained after the administration of cholecystokinin pancreozymin, whereas the central branches increased in width The arterial filling phase and the arterial phase of the liver were prolonged The portal vein was similarly affected, its width increased and the transit time did not shorten as was to be expected as a result of the increased blood flow through the pancreas and the small intestine The cause of the increased vascular resistance in the liver is a little puzzling but should probably be sought for in increased intrahepatic pressure One hypothesis could be that the sudden increase in bile production after cholecystokinin pancreozymin (Jonson et coll 1964) and the inelastic capsule of the liver leads to an increase in the intrahepatic pressure

Small intestine Cholecystokinin pancreozymin produced contraction of both the longitudinal and circular muscles of the small intestine Activity implies a higher oxygen consumption and is associated with an increased blood flow The diameter of the mesenteric arteries increased, the arterial filling phase and the arterial phase shortened and consequently the peripheral resistance in the vascular bed decreased The cause must be sought for in an opening of the capillaries to correspond to increased oxygen consumption

The mean values for arterial filling phase arterial phase and maximal contrast concentration of the portal vein are higher in this material than normal Seven patients suffered from portal hypertension the vascular resistance in the mesenteric vessels was thus high and the circulation time longer than normal

Reflux The reflux to the aorta from the celiac artery and the superior mesenteric artery was the same after the preparation The peripheral vascular re istance increa ed in the celiac artery and decrea ed in the superior me enteric artery The unaltered reflux to the aorta could thus be explained by an increase from the celiac artery and decreased reflux from the uperior me enteric artery

Pancreas An increase of the blood flow through the pancreas was obtained after cholecystokinin pancreozymin as after ecretin although to a lower degree It was not possible to decide whether this was an effect of cholecystokinin pancreozymin or of the secretin impurity

Conclusions

Cholecystokinin pancreozymin increases the blood flow through the gall bladder o that the wall is outlined by the greater amount of contrast medium reaching the cystic artery during a horter time The contracture of the mu culatures of the gallbladder by the preparation increa es the oxygen con sumption and thus further augments the blood flow

The peripheral resistance increases in both the arterial and portal systems of the liver after cholecystokinin pancreozymin The blood flow rate decreases the peripheral arteries in the liver are contracted and the central vessels are widened The preparation increases both the blood flow rate through the small intestine and the width of mesenteric vessels to correspond to the greater oxygen consumption in the small bowel

It was not po sible to determine the effect of the preparation on the pancreas because it contained secretin impurity However, the blood flow through the pan creas increased to a slight degree possibly explained by the presence of the secretin

Acknowledgement

The cholecystokinin pancreozymin preparation was obtained from Prof E Jorpes Stock holm

SUMMARY

Twenty patients were investigated by celiac and superior mesenteric angiography both with and without previous intraarterial injection of cholecystokinin pancreozymin This preparation increased the blood flow through the gallbl dder and the small intestine and enabled the wall of the gallbladder to be demonstrated The method of examination is described in detail

ZUSAMMENFASSUNG

Es wurden 20 Patienten mit Angiographie der A. coeliaca und der A. mesenterica so wohl mit als auch ohne vorherige arterielle Injektion von Cholezystokinin-Pankreozymin untersucht. Dieses Präparat verstärkt die Durchblutung der Gallenblase und des Dünndarms und ermöglicht es, die Wand der Gallenblase darzustellen. Die Untersuchungsmethode wird im einzelnen beschrieben.

RÉSUMÉ

Vingt malades ont eu une angiographie du tronc cœliaque et de l'artère mésentérique supérieure, avec et sans injection intra-artérielle préalable de cholécystokinine-pancréozymine. Ce produit augmente le débit sanguin dans la vésicule biliaire et l'intestin grêle et a permis de mettre en évidence la paroi de la vésicule biliaire. L'auteur décrit en détail cette méthode d'examen.

REFERENCES

BRODÉN B.: Experiments with cholecystokinin in cholecystography. Acta radiol. 49 (1958) 25.

DAHLGREN S.: The afferent loop syndrom. Acta chir. scand. (1964) Suppl. No. 327, p. 115.

GREITZ T.: A radiologic study of the brain circulation by rapid serial angiography of the carotid artery. Acta radiol. (1956) Suppl. No. 140.

HEDNER P., PERSSON H. and RORSMAN G.: Effect of cholecystokinin on small intestine. Acta Physiol. scand. 70 (1967) 250.

JONSON G., SUNDMAN L. and THULIN L.: The influence of chemically pure secretin on hepatic bile output. Acta physiol. scand. 62 (1964) 287.

JORPES E. and MUTT V.: Cholecystokinin and pancreozymin, one single hormone? Acta physiol. scand. 66 (1966) 196.

MIKAELSSON C. G.: Polythene catheter of new shape for percutaneous selective catheterization. Acta radiol. Diagnosis 3 (1965) 581.

PETRÉN T.: Die Venen der Gallenblase und der extrahepatischen Gallenwege beim Menschen und bei den Wirbeltieren. Dissertation. Stockholm 1933.

UDÉN R.: Effect of secretin in celiac and superior mesenteric angiography. Acta radiol. Diagnosis 8 (1969) 497.

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ANGIOGRAPHY IN CARCINOMA AT THE PAPILLA OF VATER

by

OLLE OLSSON and ULF TYLEN

Angiography is often used in the clinical investigation of obstructive jaundice especially in possible carcinoma of the pancreas Carcinoma of the papilla of Vater although less common than other growths in this region represents however a cause of obstructive jaundice to be kept in mind

The literature on angiography of this type of carcinoma is sparse LUNDERQUIST (1965) included in his material six patients with carcinoma of the caudal part of the common bile duct and the papilla of Vater The angiographic appearances in two patients with tumours measuring 2 cm $\times$ 2 cm were normal and only slight angiographic changes were evident in one patient. A large tumour extending up into the hilum of the liver produced gross angiographic changes in 2 patients One patient operated upon for carcinoma of the papilla of Vater had a well demonstrable tumour at the site of a previous choledochoduodenostomy REUTER et coll (1970) performed angiography in 20 patients with carcinoma of the biliary tract 4 of whom had carcinoma of the common bile duct and 2 of the ampulla of Vater These two tumours 2 and 6 cm in diameter at operation produced angiographic abnormalities consisting of minor encasement of the pancreaticoduodenal arcades or their branches

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Contrast medium accumulation was minimal and no venous abnormalities were present, although the larger tumour had invaded both the pancreas and the duodenum and the smaller tumour had commenced to infiltrate the adjacent pancreas.

Pathology. The typical duodenal papilla tumour is considered to be an adenocarcinoma with soft villi and a mainly central artery (HENKE & LUBARSCH 1929). It bears a marked resemblance to certain tumours of the urinary bladder. Some papilla of Vater neoplasms are, however, more dense, of a scirrhous type and contain a few vessels. The neoplasms of the distal part of the common bile duct usually have this scirrhous structure although fungating or arborescent growth is sometimes present. The tumours may present themselves as hemispheric masses 1 to 3 cm in diameter. The common bile duct is usually dilated.

The pathology of carcinoma of the papilla of Vater is sometimes complicated. Goblet cells are often present in the region where the pancreatic duct and the common bile duct open at the duodenal papilla. This sometimes makes the diagnosis as to the exact origin of the tumour in this region difficult or impossible. Neoplasms may arise from the terminal third of the common bile duct, from the lining epithelium of the intestinal mucosa, from the true ampulla and under exceedingly rare circumstances from Brunner's glands (ACKERMAN 1968). Thus carcinoma of the papilla of Vater "is at times a debatable lesion" (CHRISTOPHER 1968). Carcinoma of the papilla of Vater sometimes, however, has a characteristic structure much different from the type of neoplasm in the distal part of the common duct.

Tumours have been chosen for this paper that at operation had been found to represent carcinomas arising in the papilla of Vater or involving the bile duct distally, including the papilla. The neoplasm was an adenocarcinoma of the papilla of Vater in 4 patients, an adenocarcinoma of the distal part of the common bile duct including the papilla of Vater in 2 patients and an adenocarcinoma only of the distal part of the common bile duct in 4 patients. Two of these patients had slight infiltration of the pancreas around the duct. Carcinoma of the common bile duct was proved by pathology to be running into the hilum of the liver in 3 patients, in one of these microscopy was performed only on a lymph gland. Surgical exploration revealed a papilla carcinoma in one patient but histologic examination was not performed. More details on the selection will be given in the discussion.

Anatomy. The distal part of the common bile duct is directed slightly to the right towards the lateral part of the head of the pancreas, then passes from behind through the pancreatic tissue to form the short intramural part and thus into the posterior medial wall of the second part of the duodenum. The common bile

duct and the pancreatic duct join and usually form a common opening at the papilla of Vater 8 to 10 cm from the pylorus (STIRLING 1957 MICHELS 1969) The common bile duct above this is situated retroduodenally and upra duodenally partly in the hepatoduodenal ligament The length of the duct may vary con iderably becau e of the inconstant position of the opening of the cystic duct into the hepatic duct

The ga troduodenal artery is aid to lie to the left of the common bile duct However when dilated the duct may cross behind the gastroduodenal artery and then be ituated behind or to its left branches from this artery and from the right hepatic artery feed the duct

The posterior uperior pancreaticoduodenal artery from the gastroduodenal artery crosses the duct anteriorly and descends along the right ide of the duct to cro s it posteriorly Branches from this artery directed upwards and down wards feed the common bile duct The distal part of the common bile duct is in clo e relation to the posterior pancreaticoduodenal arcade A detailed de cription of the anatomy and roentgen anatomy of the vessels in the region of the papilla of Vater the distal part of the common bile duct and the head of the pancreas is given by LUNDERQUIST (1965) a description of the blood supply to the gall bladder by MICHELS (1969) The angiographic appearances are discussed by ROSCH et coll (1969) and others

Material Patients with probable carcinoma of the papilla of Vater or of the distal part of the common bile duct were elected from a material of malignancy around this region A patient 84 years of age in whom only exploration and drainage without biopsy were performed is included This makes a total of 14 patients Three patients with a growth of the common bile duct involving the hepatoduodenal ligament with metastases to the hilum of the liver belong to those elected but are not de cribed in detail all had marked angiographic changes The same holds for a patient previously operated on for an ampulla of Vater carcinoma without previous angiography later pre enting a recurrence with marked angiographic changes All patients in whom the papilla region was involved from primary growths in the pancreas duodenum gallbladder or bile ducts proximal to the common bile duct were al o excluded

The material thus consists of 14 patients with carcinoma at the papilla of Vater either primary or arising in the distal part of the common bile duct With the exclusion of 4 patients for the rea ons given 10 patients with malignancy confined to the region remain

The discussion on angiographic findings is based partly on rea essment of films from the angiographic procedures in an attempt to arrive at an opinion as to the angiographic possibilities in this rare but diagnostically important type of tumour

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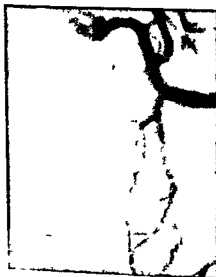


a



b

Fig 2 (For legend see opposite page)



a



b

Fig 3 (For legend see opposite page)

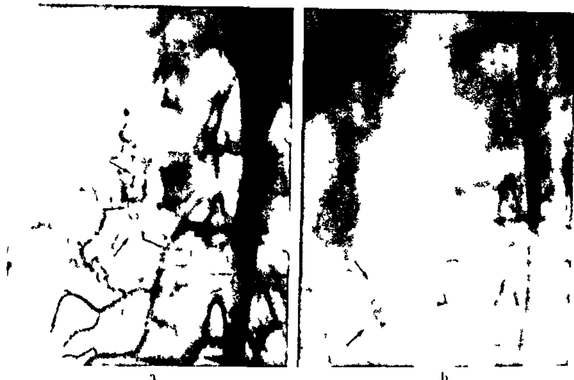


Fig. 1. Case 1. a) Encroachment upon first branch (directed caudally and situated immediately medial to the gastroduodenal artery) of the superior posterior pancreaticoduodenal artery (→). b) Capillary phase. 2.5 cm tumour with accumulation of contrast medium in its lateral half (→).

Case reports

Case 1. Female, aged 67, had been admitted to a local hospital with jaundice for one month, pain and a rise in temperature. Choledochotomy revealed no stone but a soft necrotic tumour in the region of the papilla of Vater proved to be an adenocarcinoma. She was transferred to us. Combined celiac and superior mesenteric angiography disclosed increased vascularity along the bile duct. The first branch of the superior posterior pancreaticoduodenal artery was directed distally and the wall infiltrated for 2 cm, the middle of the second branch was also infiltrated. Anterior arcade normal. A tumour 2.5 cm in diameter corresponded to the arterial changes in the capillary phase.

Pancreaticoduodenectomy was performed. A tumour 15 mm in size at the papilla proved to be an adenocarcinoma.

Fig. 2. Case 2. a) Branch from the gastroduodenal artery distal to superior posterior pancreaticoduodenal artery embraces the enlarged common bile duct (→). Caudal to pancreaticoduodenal arcade fine arteries with irregular walls immediately medial to proximal part of right ureter which is curved laterally ([illegible]). b) Transhepatic cholangiography. Enlarged duct. Stenosis distally. Right ureter displaced.

Fig. 3. Case 3. a) Enlarged gallbladder. Superior posterior pancreaticoduodenal artery runs laterally to displaced gastroduodenal artery with many branches, some infiltrated, embracing common bile duct. b) Transhepatic cholangiography. Growth in distal part of enlarged common bile duct.



a b

Fig 6 Case 6 a) Irregular infiltrated branches corresponding to distal part of common bile duct (→) above superior posterior pancreaticoduodenal artery b) Transhepatic cholangiography Enlarged duct blocked distally

Case 4 Male aged 46 with jaundice for six weeks Combined celiac and superior mesenteric angiography demonstrated that the gallbladder was enlarged with slight displacement upwards of the common hepatic artery by widened ducts Branches from the posterior superior pancreaticoduodenal artery were distended and encased in an area about 3 to 4 *cm* in diameter *Operation* revealed an enlarged gallbladder and ducts with no passage of contrast medium to the duodenum and a 2 cm×2 cm adenocarcinoma in the papilla of Vater

Case 5 Female aged 84 with increasing jaundice for one month Celiac angiography indicated an enlarged gallbladder Branches from the superior posterior pancreaticoduodenal artery embraced the enlarged bile duct encroachment in some of these arteries and tumour vessels were present Cholecystojejunostomy but no radical operation because of patient's age A small tumour was present at the papilla

Case 6 Female aged 57 with jaundice for six weeks Choledochotomy disclosed an enlarged duct but no stones and operative cholangiography an enlarged gallbladder with dilated bile ducts and stenosis distally in the common bile duct Celiac angiography one week later (somewhat incomplete examination because of patient's inability to cooperate) revealed an enlarged gallbladder with irregular branches from the convexity of posterior



Fig. 4



Fig. 5

Fig. 4. Case 4. Gastroduodenal artery and superior posterior pancreaticoduodenal artery running in a caudal direction are both stretched with branches from the latter distended and infiltrated (→).

Fig. 5. Case 5. Enlarged gallbladder. Fine arteries medial and lateral to gastroduodenal artery embrace common bile duct with tumour vessels lateral to gastroduodenal artery.

Case 2. Male aged 49 with anorexia and loss of weight for a month and slight jaundice. Previous cholecystectomy for stone. Combined celiac and superior mesenteric angiography demonstrated that numerous secondary branches from a branch of the gastroduodenal artery fed an enlarged bile duct, one artery making a convex curve distally, probably around the duct. Fine arterial branches and a few pathologic vessels corresponded to a growth displacing the upper part of the right ureter to the right. Transhepatic cholangiography revealed *enlarged ducts and stenosis of the distal part of the common duct corresponding* to the angiographic changes. Pancreaticoduodenectomy indicated an adenocarcinoma of the papilla of Vater.

Case 3. Male aged 54 with slight jaundice for ten days. Combined celiac and superior mesenteric angiography revealed an enlarged gallbladder supplied by two arteries. Gastroduodenal artery slightly displaced in a curve medially with considerable vascularity laterally along the common bile duct. A number of fine irregular arteries embracing the enlarged distal part of the duct represented branches from the posterior superior pancreaticoduodenal artery and tumour vessels, some of these small branches were infiltrated. Transhepatic cholangiography revealed wide ducts and a tumour distally corresponding to the angiographic changes. Pancreaticoduodenectomy disclosed a tumour 2 cm×3.5 cm in size at the papilla of Vater. This proved to be an adenocarcinoma.



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Fig. 4



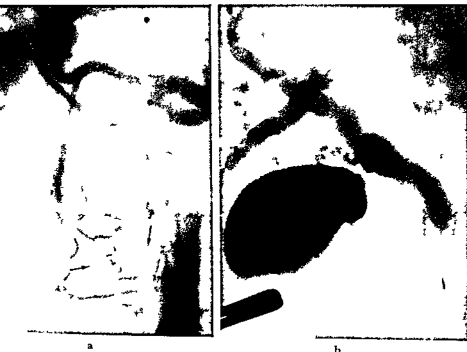
Fig. 5

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Case 6 Female aged 57 with jaundice for six weeks Choledochotomy disclosed an enlarg d duct but no stones and op rative cholangiography an enlarg d gallbladder with dilated bile ducts and stenosis distally in the common bile duct Celiac angiography one week later somewhat incomplete examination because of patient s inability to cooperate, revealed an enlarged gallbladder with irregular branches from the convexity of posterior



Fig. 7. Case 7. a) Enlarged gallbladder. Fine arteries medial to gastroduodenal artery branches embrace widened bile duct (→) with tumour vessels adjacent to distal part of gastroduodenal artery (↔). b) Transhepatic cholangiography. Enlarged duct blocked distally.

superior pancreaticoduodenal arcade curving to widened distal part of the common bile duct or the periphery of a tumour. Pancreaticoduodenectomy revealed an adenocarcinoma in the distal part of the common bile duct involving the papilla of Vater.

Case 7. Male, aged 57, with jaundice for six weeks. Combined celiac and superior mesenteric angiography revealed enlarged gallbladder with slight displacement to the left of gastroduodenal artery and increased vascularity to enlarged common bile duct with embracing of arterial branches. Fine tumour vessels medial to distal part of gastroduodenal artery demonstrable with angiography with Norexadrin. Marked tortuosity of single arcade artery of pancreatitis type. Pancreaticoduodenectomy disclosed adenocarcinoma of distal part of the common bile duct.

Case 8. Male, aged 55, with a month's history of nausea and irritation of the skin followed by jaundice. Combined celiac and superior mesenteric angiography revealed an enlarged gallbladder with the common hepatic artery displaced slightly upwards. There was delayed filling of the posterior superior pancreaticoduodenal artery, the beginning of which was encased for 2 cm lateral to the gastroduodenal artery. Increased vascularity to the common bile duct, which was surrounded by fine, irregular, curved arteries that formed a vascular cylinder in the wall of the duct. Displacement of proximal part of right ureter at the site of the vascular changes corresponding to distal part of the common bile duct. Pancreaticoduodenectomy and gastrectomy performed. An adenocarcinoma lay in distal part of the common bile duct and in a small part of the body of the pancreas around the duct. The carcinoma probably arose in the bile duct.



Fig 8



Fig 9

Fig 8 Case 8 Enlarged gallbladder with common hepatic artery displaced cranially Superior posterior pancreaticoduodenal artery lateral to gastroduodenal artery encased for 2 cm (→) with fine branches embracing distal part of wide common bile duct Tumour vessels present

Fig 9 Case 9 Enlarged gallbladder Gastroduodenal artery displaced to left infiltration of several branches laterally and many tumour vessels

Case 9 Male aged 70 with atrial fibrillation old pulmonary tuberculosis and two weeks jaundice At celiac angiography the gallbladder was enlarged and the gastroduodenal artery displaced to the left displacement and encroachment upon arteries with many tumour vessels behind and to the right of this artery evident in an area 5 cm in diameter Operation disclosed a small adenocarcinoma in distal part of the common bile duct at its junction with the cystic duct

Case 10 Female aged 61 with jaundice for a few weeks Cholecystojejunostomy demonstrated enlarged gallbladder and bile ducts with a growth at distal end of the bile duct but no stone Combined celiac and superior mesenteric angiography revealed gas in gall bladder and bile duct The common duct crossed the gastroduodenal artery to the left Vascularization along the enlarged bile duct by arterial branches stemming from the superior posterior pancreaticoduodenal artery fine arteries from the dorsal pancreatic artery corresponded to irregularly infiltrated head of pancreas Branches from the superior posterior pancreaticoduodenal artery infiltrated where they anastomosed with inferior pancreaticoduodenal artery close to the superior mesenteric artery Tumour vessels and contrast medium mainly corresponding to the distal part of the common bile duct evident

Pancreaticoduodenectomy demonstrated small neoplasm and ulceration around the papilla of Vater with slight infiltration into pancreatic parenchyma and from below into the duodenal mucosa Confirmed by pathology



Fig. 10. Case 10. a) Early arterial phase. b) Late arterial phase. Infiltration of branches from dorsal pancreatic artery of head of pancreas (→). Branches from superior posterior pancreaticoduodenal artery encased. Tumour vessels mainly lateral to superior mesenteric artery correspond to distal part of common bile duct.

Discussion

Patients with a tumour of the papilla of Vater are usually not submitted to angiography. Obstructive jaundice often calls for direct surgical intervention for relief of biliary stasis, this including exploration, which often reveals the cause of the jaundice. A suggestion of carcinoma of the pancreas is usually the main indication for angiography in a growth of the papilla of Vater. The differential diagnosis data are consequently of prime importance. The symptoms in carcinoma in the papilla of Vater bring the patient under medical observation at an early stage of his disease. All of the patients in this series thus had a history of jaundice from only one to six weeks before examination. The tumour is therefore almost always extremely small (Robbins). The neoplasm in this series often did not exceed 2 cm × 2 cm. The growth in 3 of the 14 patients was, however, in spite of a short history, fairly large with metastases in the hilum of the liver

The angiographic criteria in this material as related to the common bile duct usually consisted of an increased arterial supply with branches from the posterior superior pancreaticoduodenal artery running in a cranial and caudal direction along the duct Branches crossing the duct and curving around the duct thus indicating its enlargement were often evident Such arteries could be single or multiple Enlargement of the gallbladder together with the bile duct sometimes caused displacement of the gastroduodenal artery in a gradual curve to the left

Encroachment upon branches from the superior pancreaticoduodenal artery or directly from the gastroduodenal artery was present in 9 of the 10 patients and in the 4 patients excluded from detailed description Tumour vessels were evident in 8 of the 10 patients as well as in the other 4 patients excluded Tumour vessels were absent under ordinary examination conditions in one patient but appeared at angiography with Norexadrin (BOIJSEN & REDMAN 1967) The tumour tissue was sufficiently rich in capillaries in only 2 patients to make the tumour demonstrable in the capillary phase

The changes at the extremity of the common bile duct were sometimes of the same type or had a close resemblance to those in carcinoma of the head of the pancreas Involvement of specific pancreatic arteries as the dorsal pancreatic artery in Case 10 was a definite sign of infiltration of the head of the pancreas

Angiographic findings regarding the gallbladder are also of diagnostic importance One patient had undergone cholecystectomy and 3 patients had had drainage of the common bile duct before the angiographic procedure The gall bladder was nevertheless moderately enlarged in 2 of these 3 last mentioned patients but considerably increased in size in the remaining 6 patients ROBBINS (1962) stated in only approximately half of the cases of obstruction due to neoplasia is the gallbladder enlarged This is not true in the present material where conditions regarding enlargement of the gallbladder follow Courvoisier's law A palpable gallbladder in obstructive jaundice suggests a cause for jaundice other than gallstone

The fact that the gallbladder is usually markedly distended which is easily recognized in the angiogram and that the duct is enlarged must constitute signs for a close investigation of the region of the common duct the papilla and the head of the pancreas

It must be emphasized that the changes in carcinoma of the papilla of Vater and of the distal part of the bile duct cannot be definitely distinguished from the slight changes in carcinoma in the head of the pancreas involving the region of the bile duct and the papilla Carcinoma of the pancreas usually produces changes in arteries other than those now being considered A small carcinoma of the pancreas involving the ampulla may cause signs of the same type as a growth of the ampulla affecting or not affecting the pancreas



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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, NATIONAL INSTITUTES OF HEALTH, BETHESDA MARYLAND, U S A

BLOOD BORNE METASTASES TO THE KIDNEY

Angiographic investigation of three vascular tumors

by

P M SHIMKIN, J S BUCHIGNANI and M S SOLOWAY

Hematogenously disseminated metastatic neoplasm to the kidney is infrequently diagnosed pre mortem The few angiographic investigations of previous reports have most frequently disclosed lesions without tumor circulation (BOSNIAK et coll 1969 KAHN & WISE 1968) This communication presents the angiographic findings in 3 cases of vascular secondary renal tumors one with enhanced demonstration of tumor vessels after administration of intra arterial epinephrine and the 2 others with signs of renal vein obstruction

Case reports

Case 1 Widespread metastatic testicular choriocarcinoma had been diagnosed in this 42 year old male in Nov 1967 An urography at this time was normal Prolonged systemic chemotherapy achieved complete regression of palpable lymph node metastases by Sept 1968 One month before his terminal admission in Jan 1969 the patient experienced first dull low back pain and then aching in the lower abdomen made worse by lying on his side Physical examination disclosed a grapefruit sized mass in the left flank and enlarged supraclavicular lymph nodes A roentgen examination of the chest revealed multiple nodular pulmonary metastases Proteinuria and innumerable red blood cells were present in urinary specimens urinary cytology was positive on several occasions for neoplastic cells

Submitted for publication 1 March 1971

The important point is that tumours in the distal part of the common bil duct and papilla of Vater, even when fairly small, can be diagnosed or at lea suggested by angiography, as in all of the present 14 patients The angiographi examination should be beyond reproach, especially as regards suitable selectivit and correct projection It is also necessary that the film quality should be high

SUMMARY

A material of 14 patients with obstructive jaundice was examined by angiography Th revealed encroachment upon certain arteries and tumour vessels The gallbladder and th bile duct were usually enlarged as well The differential diagnosis between carcinoma o the pancreas and a growth in the distal part of the common bile duct and the papilla o Vater is discussed

ZUSAMMENFASSUNG

Ein Material von 14 Patienten mit Stauungsikterus wurde angiographisch untersucht *Dabei* wurde eine *Infiltration* gewisser Arterien und *Gefässe* von Tumoren nachgewiesen Die Gallenblase und der Gallengang waren dabei gewöhnlich auch erweitert Die Differentialdiagnose zwischen einem Pankreaskarzinom und einem Tumor in dem distalen Teil des gemeinsamen Gallengangs und die Papilla Vateri wird diskutiert

RÉSUMÉ

Quatorze malades atteints d'ictère par obstruction ont été examinés par angiographie Cet examen a montré une infiltration de certaines artères et des vaisseaux tumoraux *Dans* la plupart des cas la vésicule et les voies biliaires étaient dilatées Les auteurs étudient le diagnostic différentiel entre le cancer du pancréas et une tumeur de la partie distale du cholédoque et de la papille de Vater

REFERENCES

ACKERMAN L V Surgical pathology C V Mosby Saint Louis 1968

BOIJSEN E and REDMAN H Effect of epinephrine on celiac and *superior mesenteric angio*graphy Invest Radiol 2 (1967) 184

CHRISTOPHER F Textbook of surgery W B Saunders London 1968

HENKE F und LUBARSCH O Handbuch der speziellen Patho Anatomie und Histologie IV 3 V 2 Springer Verlag Berlin 1929

LUNDERQUIST A Angiography in carcinoma of the pancreas Acta radiol (1965) Suppl No 235

MICHELS N A Blood supply and anatomy of the upper abdominal organs J B Lippincott Philadelphia and Montreal 1969

REUTER S REDMAN H and BOOKSTEIN J Differential problems in the angiographic diagnosis of carcinoma of the pancreas Radiology 96 (1970) 93

ROBBINS S L Textbook of pathology with clinical application W B SAUNDERS London 1962

ROSCH J GROLLMAN J H and STECKEL R J Arteriography in the diagnosis of gallbladder disease Radiology 92 (1969) 1485

STIRLING W B Aortography E & S Livingstone Edinburgh 1957

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Fig 1 Case 1 Urography Lower pole left renal mass

An urography disclosed a large lower pole left renal mass (Fig 1) Selective angiography of the main left renal artery (Fig 2 a—c) disclosed decreased caliber of the lower pole vessels with occasional areas of tumor encasement of smaller branches and one abrupt termination of a third order vessel Several small irregular vessels were present particularly in the upper part of the tumor the interface between tumor and normal kidney was ill defined In the venous phase the renal vein was not contrast filled however a large number of collateral veins were demonstrated Selective angiography of a left lower pole accessory renal artery (Fig 3) disclosed a few clusters of fine tumor vessels and a diffuse accumulation of contrast medium within the inner quadrant of the mass

The patient succumbed to widespread metastatic disease a month after the angiographic investigation At microscopic examination the tumor was found to be an embryonal cell carcinoma There was a bland thrombus of the left renal vein Extensive retroperitoneal lymph node metastases were found at autopsy and the left renal vein was slightly compressed

Case 2 In Jan 1970 a single pulmonary metastasis was first discovered in this 17 year old male who had previously undergone an upper extremity amputation for synovial sarcoma The presumed solitary pulmonary metastasis was resected Post operatively the

Fig 2 Same case as fig 1 Angiography of the main renal artery a) Arterial phase b) Capillary phase Arterial encasement and sparse tumor vessels c) Venous phase Renal venous collaterals (→) renal vein not demonstrated d) Angiography of the inferior accessory renal artery Small tumor vessels and accumulation of contrast medium within the inner quadrant of the mass



Fig 2 (For legend see opposite page)

patient was well for 9 months when he experienced repeated episodes of left flank pain General physical examination was normal, neurologic examination revealed signs of a parietal lobe lesion Routine urinalysis was normal a specimen for cytology suggested neoplastic cells

The urography (Fig 3 a) disclosed a large lower pole left renal mass displacing the proximal part of the ureter medially there was in addition a right retroperitoneal mass displacing the ureter at the L5—S1 level A selective angiography (Fig 3 b) demonstrated a moderate number of tumor vessels A repeat angiography after the intra arterial administration of 10 mg epinephrine (Fig 3 c) provided enhancement of the findings At left carotid angiography 2 avascular parietal lobe tumors were demonstrated selective injection of the right 4th lumbar artery demonstrated the retroperitoneal mass to be slightly vascular

The patient rapidly expired from his widespread metastatic disease Autopsy was not performed

Case 3 This 57 year old male cigarette smoker had a 2 year history of about 10 kg weight loss 6 months of increasingly severe right upper quadrant pains 2 months intermittent gross hematuria and 6 weeks before admission an episode of hemoptysis Physical examination disclosed an ill defined tender right upper quadrant mass Three specimens for urinary cytology contained cells suggestive of an epithelial malignancy A roentgen examination of the chest disclosed a right hilar tumor bronchial biopsy of the lesion established the diagnosis of squamous cell bronchogenic carcinoma

An urography 3 weeks before angiography disclosed a right upper pole renal mass with invasion and obliteration of the upper pole calyces and superior renal pelvis This was more clearly demonstrated at a subsequent retrograde pyelography (Fig 4 a) Urography the day of angiography revealed non function of the right kidney

Angiography (Fig 4 b) revealed the intrarenal branches of the renal artery to be stretched but not displaced by the mass Several of the intrarenal arteries showed tumor encasement Fine profuse neovascularity was present The renal vein was not demonstrated, however numerous renal collateral veins were

Nephrectomy disclosed a poorly differentiated squamous cell carcinoma diffusely infiltrating most of the substance of the right kidney and invading the renal collecting system and the renal vein

Discussion

At autopsy, WILLIS found blood borne metastases to the kidney in 38 of 500 patients dying of malignant disease, an incidence of 7 6 % In most instances the metastases were multiple and bilateral The size of the individual deposit seldom exceeded 2 cm The usual location of the tumors within the kidney was cortical and frequently subcapsular The tumor deposits enlarge mainly by interstitial infiltration of surrounding renal parenchyma The renal capsule frequently limits outward growth of tumor Tumor infiltration into the medulla often assumes a radial appearance conforming to the architecture of the medullary rays Veins and venules frequently suffer invasion Excluding lymphoma and leukemia, hematogenous metastatic disease of the kidney is most commonly due to carcinoma



Fig 3 Case ? a) Urography Lower pole left renal mass displacing collecting system anteriorly and superiorly b) Angiography Moderate number of tumor essels c) Angiography Moderate number of tumor vessels c) Angiography after intra arterial administration of epinephrine Demonstration of tumor vessels is enhanced A normal lumbar artery is also filled from aort c backflow of contrast medium injected into the renal artery

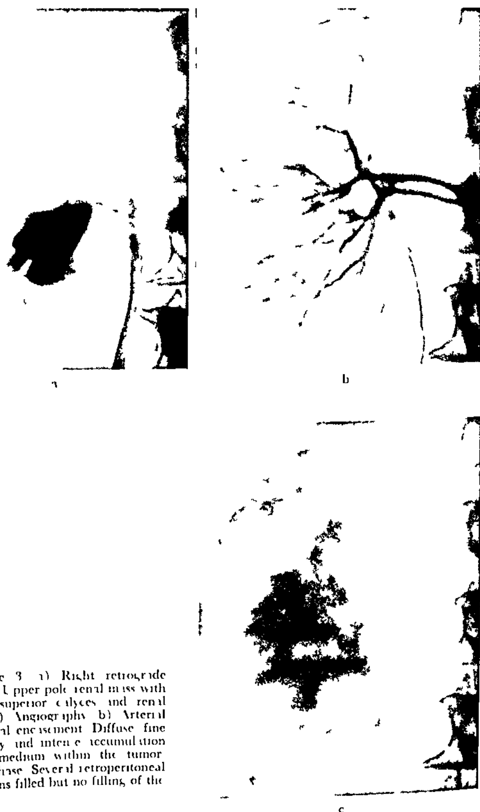


Fig. 1. Case 3. a) Right retrograde pyelography. Upper pole renal mass with invasion of superior calyces and renal pelvis. b), c) Angiography. b) Arterial phase. Arterial encasement. Diffuse fine neovascularity and intense accumulation of contrast medium within the tumor. c) Venous phase. Several retroperitoneal collateral veins filled but no filling of the renal vein.

of the lung although its occurrence with a multiplicity of primary growths has been recorded (KLINGER 1951, NEWSAM & TULLOCH 1966 WILLIS 1952)

Patients with secondary kidney tumors seldom have symptoms or signs although urinalysis is often abnormal (KLINGER 1951) Because these tumors are so frequently small asymptomatic and associated with disseminated malignancy, they are seldom diagnosed pre mortem The great majority of reported secondary renal tumors discovered pre mortem have been large with symptoms or signs

BOSNIAK et coll have reported the largest series of secondary kidney tumors investigated angiographically The 4 primary lesions were epidermoid carcinoma of the lung (2 cases) myxoliposarcoma of the leg and uterine choriocarcinoma All 4 cases showed the similar angiographic features of an avascular or hypovascular mass without tumor vessels The 2 cases with lung metastases showed irregularity and amputation of small branch vessels in the region of the mass indicating tumor encasement Nephrotomography was performed in 3 cases in all the mass was shown not to be a simple cyst Nephrotomography thus greatly complemented the minor angiographic abnormalities in establishing the malignant nature of the lesion

On the basis of 3 cases KAHN & WISE described secondary renal tumors angiographically as space occupying hypovascular lesions One of their cases a metastatic melanoma was illustrated the histology of the primary neoplasm in the other 2 cases was not mentioned

Our 3 cases plus scattered case reports in the literature have exhibited more vascular changes than those documented by the above series In a case of bilateral secondary renal tumors from a primary thyroid carcinoma selective angiography demonstrated both to be flagrantly vascular with prominent tumor vessels (TAKAYASU et coll 1968) Selective angiography of a kidney metastasis from a squamous cell carcinoma of the larynx disclosed narrowing of smaller vessels in the region of the mass sparse tumor vessels and a well defined accumulation of contrast medium within the tumor (SILBER & BOWLES 1969) Hence a spectrum of angiographic changes has been encountered The degree of vascularity and the presence of tumor encasement seem in part related to the nature of the primary neoplasm

The findings of arterial tumor encasement and lack of tumor vessels observed by BOSNIAK et coll in their 2 cases of lung metastases are similar to those described by MITTY et coll for carcinoma of the renal pelvis with infiltration into the kidney substance As secondary renal tumors are often cortical in origin radiographic differentiation from invasive carcinoma of the renal pelvis may be suggested from the urographic or pyelographic findings However if the secondary renal tumor infiltrates deeply into the renal medulla and involves the pelvocalyceal system (as with our case 3) urographic differentiation from

carcinoma of the renal pelvis is impossible (NEWSAM & TULLOCH 1966)

Our case of metastatic lung carcinoma, in addition to having arterial tumor encasement, displayed extensive fine neovascularity and intense accumulation of contrast medium within the tumor, both previously undescribed with this neoplasm when metastatic to the kidney The similarity to invasive carcinoma of the renal pelvis is noted again Although invasive renal pelvis carcinoma is most often avascular (MITTY et coll 1969), occasionally angiography will disclose considerable vascularity (WATSON et coll 1968)

The improvement in contrast filling of tumor vessels after intra arterial administration of epinephrine in our second case is apparently the first reported demonstration of this phenomenon in secondary kidney tumors BOSNIAK et coll utilized intra arterial epinephrine in 2 of their 4 cases, in neither were tumor vessels disclosed In none of the 3 cases of KAHN & WISE were tumor vessels demonstrated after intra arterial epinephrine

In 2 of our cases the renal vein did not fill but concomitant demonstration of abundant renal collateral veins prompted the correct diagnosis of obstruction of the renal vein This is apparently the first reported angiographic demonstration of renal vein obstruction with metastatic tumor to the kidney WILLIS described frequent venous invasion by secondary renal tumors The pathogenesis of the bland thrombosis of the renal vein found at autopsy in our first cases is obscure Nonetheless our 2 cases uphold the angiographic rule that demonstration of renal vein obstruction in the presence of a renal mass is good substantiation of its malignant nature (FOLIN 1967)

SUMMARY

Angiographic investigation of 3 cases of secondary renal tumors disclosed each to be vascular the lung metastasis especially so Two cases (embryonal cell and bronchogenic carcinomas) exhibited arterial tumor encasement and renal vein obstruction Demonstration of tumor vessels within the metastasis from the synovial sarcoma was enhanced following intra arterial epinephrine These observations broaden the spectrum of angiographic findings previously encountered with secondary renal tumors

ZUSAMMENFASSUNG

Angiographische Untersuchungen bei 3 Fallen eines sekundären Nierentumors ergaben fur jeden von diesen das Vorhandensein von Gefassen besonders in Lungenmetastasen Zwei Falle (Embryonalzellen und Bronchial Karzinome) zeigten arterielle Tumor Einschlusse und Nierenvenen Obstruktionen Der Nachweis von Tumorgefässen innerhalb einer Metastase eines Synovial Sarcoms war nach intra arterieller Adrenalin Injektion verbessert Diese Beobachtungen erweitern das Spektrum der angiographischen Befunde auf die zuvor [illegible] gestossen worden ist

RÉSUMÉ

L examen angiographique de trois cas de tumeur renale secondaire a montre qu elles sont toutes vasculaires specialement la metastase pulmonaire Dans deux cas (cancer a cellules *embryonnaires et cancer bron hogenique)* il y avait un *enchassement* arteriel de la tumeur et une obstruction de la veine renale L injection intra arterielle d adrenaline a favorise la mise en evidence de vaisseaux tumoraux dans la metastase de sarcome synovial Ces obser vations enrichissent l eventail d s signes angiographiques decrits jusqu a maintenant dans les tumeurs renales secondaires

REFERENCES

Bosniak M A Stern W Lopez F et coll Metastatic neoplasm to the kidney A report of four cases studied with angiography and nephrotomography Radiology 92 (1969) 989

Folin J Angiography in renal tumors Its value in diagnosis and differential diagnosis as a complement to conventional methods Acta radiol (1967) Suppl No 267

Kahn P C and Wise H R The use of epinephrine in selective angiography of renal masses J Urol 99 (1968) 133

Klinger M *Secondary tumors of the genito urinary tract J Urol 65 (1951) 144*

Mitty H A Baron M G and Feller M Infiltrating carcinoma of the renal pelvis an iographic features Radiology 92 (1968) 994

Newsam J E and Tulloch W S Metastatic tumors in the kidney Brit J Urol 38 (1966) 1

Silber I and Bowles W T A case of epidermoid carcinoma of the larynx with metastases to the kidney J Urol 102 (1969) 549

Takayasu H Kumamoto Y Terawaki Y and Ueno A A case of bilateral metastatic renal tumor originating from a thyroid carcinoma J Urol 100 (1968) 717

Watson R C Fleming R J and Evans J A Arteriography in the diagnosis of renal carci noma Radiology 91 (1968) 888

Willis R A The spread of tumor in the human body Second edition p 447 Butterworth & Co London 1952

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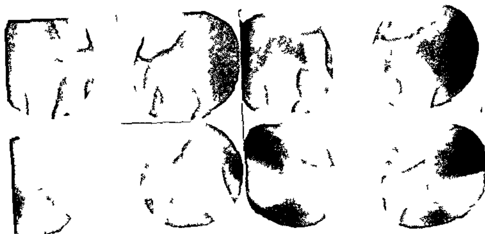


Fig 1 Roentgenograms of hip joints with hip mask protection of other regions



Fig 2 Application of hip mask in roentgenography of hip joints

The effectiveness of the mask was clearly observed in roentgenograms obtained with it in position There are several advantages in using the hip-mask in roentgen examinations of the hip joints in infants (1) There is practically no irradiation of the infant (2) the device may be made in any department (3) the same mask is used for both sexes (4) the application is simple and involves no discomfort so that the movements of the infant are minimal and (5) R and L are cut into the mask so that the sides are defined The only disadvantage of the method is that only limited areas of the pelvis appear in the film and this may in special cases lead to diagnostic difficulties an ad

FROM THE ROENTGEN DEPARTMENT (DIRECTOR R. F. FISCHEL), KAPLAN HOSPITAL, RECHOVOTH, ISRAEL

METHOD OF GONAD PROTECTION

by

R. F. FISCHEL

The increasing number of infants examined for possible congenital dislocation of the hip joint has warranted the design of a simple device for the protection of the gonads, this we have called the 'hip-mask'. The protector is cut from a 30 cm × 15 cm sheet of ordinary lead rubber, from which two round openings, 54 mm in diameter, corresponding to the hip-joints, are removed. The original masks of different sizes have now been replaced by a standard mask for all infants. It is placed upon the supine infant with the mid line at the upper border of the symphysis pubis; fixation is usually unnecessary, although the child may sometimes have to be immobilized.

The amount of radiation was measured by the lithium fluoride activated Phosphor Dosimeter (TLD) and by film badge dosimetry in the rectum, on the skin of the scrotum and the sacral and hepatic regions. The TLD method indicated no radiation within the ampulla recti (girls) or behind the scrotum. The film badge technique disclosed no radiation: liver and sacral regions in girls, liver and scrotal regions in boys. Control examinations by both methods with protection of the gonads by small pieces of lead rubber of different shapes or without protection, recorded radiation readings of 10 to 23 mR.

Submitted for publication 29 January 1971.

Books received

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ALEXANDER G H The heart and its action Roentgenkymographic studies Warren H Green St Louis 1970

ASHIZAWA S and KIDOKORO T Endoscopic color atlas of gastric diseases Georg Thieme Verlag Stuttgart 1971

BONTE G CECILE J P et PICARD J D Artériographie du membre supérieur et de la main Les monographies des Annales de Radiologie No 3 Expansion Paris 1970

BRYAN G J Diagnostic radiography A concise practical manual E. & S Livingstone Edinburgh 1970

DEBRUN G et GASQUET C Explorations vasculaires des tumeurs abdominales de l enfant Les monographies des Annales de Radiologie No 4 L Expansion Paris 1970

DECKER K und BACKMUND H Padiatrische Neuroradiologie Georg Thieme Verlag Stuttgart 1970

DEISENHAMMER E. Szintigraphische Untersuchungen in Neurologie und Neurochirurgie Bruder Hollinek Verlag Wien 1971

DOPPMAN J L. DI CHIRO G and OMMAYA A K Selective arteriography of the spinal cord Warren H Green St Louis 1969

DYNAMIC STUDIES WITH RADIOISOTOPES IN MEDICINE IAEA proceedings of a symposium Rotterdam 1970 International Atomic Energy Agency Vienna 1971

EHRENPREIS T Hirschsprung s disease Year Book Medical Publishers Chicago 1971

FUNDAMENTALS OF EAR TOMOGRAPHY Edited by J Jensen and H Rovsing Charles C Thomas Springfield 1971

HIVET M LACADEC B et POILLEUX J Chirurgie des arteres digestives Expansion Scientifique Française Paris 1970

HYPERTROPHIC OBSTRUCTIVE CARDIOMYOPATHY Ciba Foundation Study Group No 37 Edited by G E W Wolstenholme and M O Connor J & A Churchill London 1971

JACOBSON S A The comparative pathology of the tumors of bone Charles C Thomas Springfeld 1971

LEKSELL L Stereotaxis and radiosurgery An operative system Charles C Thomas Springfeld 1971

LEMAITRE G MICHEL J R et TAVERNIER J Traité de radiodiagnostic Tome VIII Appareils urinaire et génital masculin surrénales Masson & Cie Paris 1970

MARKUSKE H Untersuchungen zur Statik und Dynamik der kindlichen Halswirbelsaule Der Aussagewert seitlicher Rontgenaufnahmen Hippokrates Verlag Stuttgart 1971

METZGER J LEGRÉ J DJINDJIAN R et ENGEL PH Traité de radiodiagnostic Tome XV Neuroradiologie Masson & Cie Paris 1971

MURRAY R O and JACOBSON H G The radiology of skeletal disorders. Exercises in diagnosis Williams and Wilkins Company Baltimore 1971 and Churchill Livingstone Edinburgh 1971

PROGRESS IN PEDIATRIC RADIOLOGY Genito-urinary tract Volume 3 Edited by H J Kaufmann S Karger Basel 1970

RADIOISOTOPES IN MEDICAL DIAGNOSIS Edited by E. H Belcher and H Vetter Butterworths London 1971

RONTGENDIAGNOSTIK TECHNOLOGIE UNTERSUCHUNGSMETHODIK ORGANISATION Herausgeben von W A Fuchs und F Voegeli Hans Huber Bern 1971

ditional conventional film of the pelvis may then have to be added. The hip mask can of course not be used in newborns when the mobility of the symphysis pubis is to be examined by the method of ANDRÉN. The mask has now been used satisfactorily for five years. Only rarely have there been cases in which additional exposures were found necessary.

Acknowledgements

The author takes this opportunity of thanking J. Handsel and C. B. Sonder, the latter performed the measurements with the help of the Pasak Service and the Weizman Institute of Science, Rechovoth.

SUMMARY

A device, the hip mask, for protection of the gonads at roentgenography of the hip joints in children is described. The device is simple and effective. Measurements failed to indicate any untoward irradiation of the infant.

ZUSAMMENFASSUNG

Eine Anordnung, die Hüftmaske, zum Schutz der Geschlechtsdrüsen während Röntgenographie der Hüftgelenke wird beschrieben. Diese ist einfach und effektiv. Messungen zeigten keine unerwünschte Bestrahlung des Kindes.

RÉSUMÉ

Description d'un dispositif, le masque pour hanche, pour protéger les gonades au cours de la radiographie des articulations de la hanche chez l'enfant. Le dispositif est simple et efficace. Les mesures n'ont montré aucune irradiation indésirable chez le nourrisson.

REFERENCES

ANDRÉN L.: Instability of the pubic symphysis and congenital dislocation of the hip in newborns. The possible aetiologic role of maternal hormones. Acta radiol. 54 (1960), 123.

— Pelvic instability in newborns. With special reference to congenital dislocation of the hip and hormonal factors. Acta radiol. (1962), Suppl. No. 212.

MAGNUSSON W.: A device for the protection of the testicle in roentgen examinations of adjacent organs and bones. Acta radiol. 37 (1952), 288.

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SELECTIVE POSTMORTEM ANGIOGRAPHY OF THE POSTERIOR FOSSA

Technical considerations

by

A. MOLLER

Autopsy investigations of experimentally produced vascular displacements by stereotaxic methods have been suggested as a means of arriving at an improvement in the location of posterior fossa lesions (GREITZ et coll. to be published). This implies as a technical prerequisite that postmortem angiography of the posterior fossa be performed with the skull essentially intact.

Earlier investigations dealing with postmortem cerebral angiography have been mostly based on a non-selective technique or on selective injections in isolated autopsy specimens (MONIZ 1940, KAPLAN 1953, 1956, VANDER EECKEN & ADAMS 1953, HUTCHINSON & YATES 1956, JOHNSON & YATES 1956, STEIN et coll. 1962, RODDA & DUGDALE 1963, MATSUDA 1964, SVARE et coll. 1964, WOLLSCHLAEGER & WOLLSCHLAEGER 1966, STEPHENS & STILWELL (1969). A technique of selective postmortem vertebral angiography of the intact skull does not seem to have been published. HAUGE (1954), GALLOWAY & GREITZ (1960) and GREITZ & SJOGREN (1963) carried out selective angiographies of the vertebral artery in cadavers, the skull being opened to ligate the posterior communicating arteries. A similar method was used by HASSLER (1967 a) for

From the Department of Neuroradiology (Director Prof. T. Greitz), Karolinska Sjukhuset, Stockholm, Sweden. Submitted for publication 13 September 1971.

RYAN M J Moments with diagnostic radiology Vol 1 The abdomen W B Saunders Company London 1969

SELECKI B R and WILLIAMS H B L Injuries to the cervical spine and cord in man Australasian Medical Publishing Co Sydney 1970

SELLINK J L Examination of the small intestine by means of duodenal intubation H F Stenfert Kroese Leiden 1971

SQUIRE L F COLAIACO W M and STRUTYNSKY N Exercises in diagnostic radiology 2 The abdomen W B Saunders Company London 1971

SYMPOSIUM OSSIUM European Association of Radiology Edited by A M Jelliffe and B Strickland E & S Livingstone Edinburgh 1970

(A) TEXT BOOK OF X RAY DIAGNOSIS Volume 5 Fourth edition Edited by S C Shanks and P Kerley H K Lewis & Co London 1970

(A) TEXT BOOK OF X RAY DIAGNOSIS Volume 6 Fourth edition Edited by S C Shanks and P Kerley H K Lewis & Co London 1971

WENGEN H C Aktuelle Probleme in der Chirurgie 11 Zum Kahnbeinbruch der Hand und seine unfallmedizinische *Bedeutung Hans Huber Verlag Bern 1971*

VOGELSANG H Intraosseous spinal venography Excerpta Medica Amsterdam 1970

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF
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microangiographic examinations of the brain stem. PLAUT (1955) attempted to perform selective vertebral angiography in 15 cadavers. He observed: "The internal carotid is linked with the vertebral system by the posterior communicating arteries, which are occasionally visible in the vertebral arteriogram of the living. They are always filled in the cadaver, because there is no counter pressure from the carotid." BROWN & TATLOW (1963) tried to prevent back flow *to the carotid system through the circle of Willis by the initial injection of* a concentrated (tooth paste consistence) barium sulphate suspension into the vertebral artery. They were not successful and obtained irregular filling of the carotid arteries at the succeeding injection of a thin barium sulphate suspension into the same artery. MANI et coll. (1968) examined 30 brain specimens by vertebral angiography without publishing technical details; the skull was probably not intact at the injection of the contrast medium.

WOLF et coll. (1963) and HUANG et coll. (1967, 1969) have published several anatomic investigations of the posterior fossa veins. The experimental part of their work was based on phlebographies in removed specimens. HASSLER (1967 b) carried out microangiographic examinations of the veins of the brain stem, and emphasized the difficulties in obtaining filling in all areas. MONIZ (1940) tried to fill the dural sinuses in cadavers in situ by injecting contrast medium into both internal jugular veins and in some cases into the confluens sinuum. JOHANSSON (1954) injected the central cerebral veins from the straight sinus, as did LORENZ (1951) in some instances. These authors, as well as MONIZ, paid no particular attention to the veins of the posterior fossa in postmortem examinations. PERESE (1960) investigated the 'superficial veins of the brain from a surgical point of view'. He reported having injected the superior sagittal sinus, the lateral and straight sinuses on the same occasion through four catheters via a burr hole at the inion, as well as the internal jugular veins. The veins of the posterior fossa in his illustration were poorly filled and, as the other sinuses were not outlined at all, apparently injected through the straight sinus only. GILLOT & AARON (1964) and GILLOT et coll. (1964) carried out *postmortem phlebographies of the dural sinuses, including the cavernous sinus* by injection with an inflated balloon catheter in the upper part of one of the internal jugular veins. Their primary object of interest was not the posterior fossa, and their illustrations revealed no posterior fossa venous filling.

No technique of selective postmortem vertebral angiography without back flow *to the carotid system, and no postmortem phlebographic technique* giving satisfactory filling of the veins of the posterior fossa in situ have thus been found in the literature. It was therefore considered important to work out such techniques to provide adequate contrast filling of the posterior fossa vessels without opening the skull before the injections.



Fig 1 Postmortem vertebral arteriography Metal parts of the co-ordinate frame for the application of stereotaxic methods

Postmortem arteriography of the posterior fossa The carotid siphons were blocked bilaterally by injections of gelatine into the carotid arteries before the injection of contrast medium into the vertebral artery to prevent its backflow through the posterior communicating arteries

The distal part of the common carotid artery and its bifurcation, as well as the proximal parts of the vertebral arteries and the adjacent parts of the subclavian arteries were dissected bilaterally Short pieces of PVC tubing (5 mm/3 mm diameter) were introduced through the common carotid arteries which were tightly ligated around the tubes close to the bifurcation The external carotid arteries were tied off Hot gelatine solution (gelatine 30 g water added to 100 g) from a continuously heated steam bath was injected slowly into the carotid arteries one at a time The timing was adjusted to allow the solidifying gelatine to block the siphon but not to pass through the posterior communicating artery about 5 ml in about 30 seconds was usually required the injection being discontinued at the point when commencing resistance was encountered The cadavers as a rule were brought into the autopsy room from cold storage at + 4 C shortly before the dissection was begun Both carotid siphons were thus blocked with solid gelatine

Smaller PVC tubing (4 mm/3 mm diameter) was introduced into the larger of the two vertebral arteries and firmly ligated the contralateral vertebral artery was tied off or clamped close to its origin Mixobar Ventrikel (Astra, barium sulphate suspension 0 6 g/ml) proved a suitable contrast medium About



Fig 2 Postmortem vertebral arteriography Partial filling of the carotid siphon and the middle and anterior cerebral arteries due to incomplete blocking of the former on one side

2 to 3 ml of plain Mixobar were first injected, followed by about 1 ml of a mixture of Mixobar and gelatine (15 g gelatine + 2 to 3 g gum arabic + Mixobar up to 200 ml) The addition of gum arabic increased the elasticity of the congealed gelatine The initial injection of an ordinary barium sulphate suspension provides improved demonstration of the smaller vessels compared to the gelatine contrast mixture alone The latter is, however, necessary to close the injected vascular system and prevent leakage from the specimen on ultimate removal

Complete filling of the vertebral artery and its branches was usually achieved, supratentorially as well as infratentorially, by this technique (Fig 1) Slight filling of the carotid siphon and the main trunks of the anterior and middle cerebral arteries on the injected side occurred only in one out of 12 cases (Fig 2) The gelatine solution used initially to block the siphons may flow into and occlude the vertebral arterial territory in the case of a wide posterior communicating artery or an anomalous connection between the vertebral and carotid arteries This occurred in another of the 12 cases and prevented complete filling of the vertebral arterial system

Postmortem phlebography of the posterior fossa Preliminary injections of contrast medium by balloon catheters in both internal jugular veins indicated that some blocking of the intracranial sinuses was necessary to prevent extensive filling of the supratentorial hemispheric veins and to improve the filling of tributaries to the straight sinus An inflated balloon catheter in the most posterior part of the superior sagittal sinus provided such a block, as well as a route for additional contrast medium injections, which were found to improve the filling of the posterior fossa veins Outlining of the posterior part of the

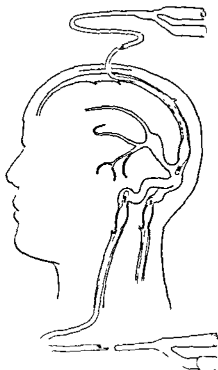


Fig 3 Positioning of the balloon catheters for posterior fossa phlebography The inflated balloons are situated in the posterior part of the superior sagittal sinus and in the upper part of both internal jugular veins

uperior sagittal inus anterior to the blocking balloon and of the posterior supratentorial veins sometimes occurred despite a high inflation pressure of the balloon However, this was found not to interfere with the investigation of the posterior fossa veins in the lateral and half axial a p views used

The following procedure was employed The internal jugular veins were dissected and a balloon catheter (Folatex 60 No 16) was introduced into each, the catheters were advanced as far towards the kull base as possible (Fig 3) The superior sagittal sinus was blocked with a balloon catheter (Folatex 60 No 12) introduced via a burr hole through the vault in the midline behind the bregma The catheter was advanced posteriorly to a position a few cm above the confluens sinuum and inflated The balloons in the jugular veins were then al o inflated to prevent retrograde filling and 20 ml Mixobar followed by 10 ml of the Mixobar gelatine mixture (of the same composition as for arteriography) were injected into each catheter 7 ml of Mixobar followed by 5 ml of Mixobar gelatine were then injected into the catheter in the superior agittal inus Successive injections of Mixobar and Mixobar gelatine were applied for the ame main reasons as in angiography i e to fill the mall veins



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Conclusions

Techniques have been developed to obtain contrast filling of the posterior fossa arteries and veins at autopsy without opening the skull Distribution of contrast medium in the intracranial arteries is in close agreement with that obtained in clinical vertebral angiography while the veins are more extensively outlined The superior sagittal sinus and the supratentorial veins are filled to a slightly greater extent than occurs in vivo this being no significant drawback These techniques thus make possible a systematic analysis of the characteristic vascular displacements caused by an experimental expansive lesion in any given position in the posterior fossa The findings compared with those obtained at vertebral angiography of clinical cases with verified tumours suggest that improved accuracy in the diagnosis of space occupying lesions of the posterior fossa is to be expected

Acknowledgement

This work was supported by a grant from the Axel och Margaret Ax son Johnsons Stiftelse

SUMMARY

New techniques of postmortem vertebral angiography and posterior fossa phlebography have been *worked out* allowing selective filling of the posterior fossa vessels with the skull essentially intact The employment of these techniques in the investigations of intracranial displacements in experimentally produced space occupying lesions is briefly described

ZUSAMMENFASSUNG

Neue Methoden fur die *postmortem vertebrale* Angiographie und Phlebographie der hinteren Schadelgrube bei intaktem Schadel wurden ausgearbeitet Die Anwendung dieser Methoden bei Untersuchungen *der Gefassverschiebungen* in experimentell hervorgerufenen raumfordernden Lasionen wird kurz beschrieben.

RÉSUMÉ

L auteur a mis au point de nouvelles techniques d angiographie vertebrale et de phlebographie de la fosse postérieure *postmortem permettant le* remplissage selectif d s vaisseaux de la fosse posterieure en laissant le *crane pratiquement* intact L auteur decrit brievement l utilisation de ces techniques pour l étude des deplacements intracraniens dans des *lesions* expansives produites *experimentalement*

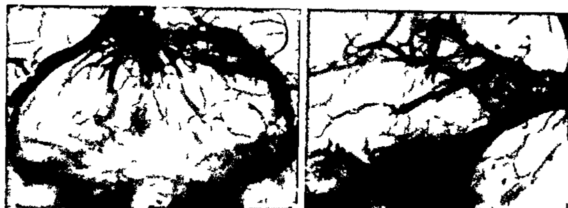


Fig 4 Postmortem phlebography of the posterior fossa The posterior supratentorial veins are outlined to some extent the inferior vermian vein is partly superimposed on the internal cerebral vein in the a p view

as completely as possible The angiographically important veins of the posterior fossa were usually adequately demonstrated by this technique (Figs 4, 5)

Examinations of the vascular displacements produced by experimental tumours in specific, well defined positions were performed in situ by the techniques described Stereotaxic methods of location and registration were applied and the results correlated with further radiologic analysis of the removed specimens, as well as with dissections These will be reported separately (CORRALES & MOLLER, MOLLER, MOLLER & CORRALES, all to be published) The posterior fossa contents were removed en bloc with the bony vault, the base of the skull and the tentorium, before this the cisterns of the posterior fossa had been filled with gelatine solution by the technique of LILIEQUIST (1959) in order to preserve the displacements and deformities caused by the experimental space occupying lesions

Fig 5 Incidence and extent of filling in postmortem phlebography of the *posterior fossa* + = Veins filled by contrast medium — = Veins not filled by contrast medium Filling in separate areas graded from + + + = extensive to (+) = poor

Cas N	Pet osal D ng G oup		H m phe c V s		Gale c Dra g Group	I f Ve mia V		P c ntral V	A t Ponto mesen V
	D	In	D	si		D	n		
1	++	++	+++	+++	+++			x	
2	(+)	—	(+)	(+)	+	—		—	—
3	+	+	+	++	++			—	
4	+++	++	+++	++	+++				
5	++	+	+++	+++	+++				—
6	+	(+)	(+)	—	—			—	—
7	+++	+++	+++	+++	+++				
8	+++	+++	+++	+++	+++				
9	+	+	++	++	+++	—			—
10	++	++	+++	+++	+++		—	—	
11	(+)	—	+	+	++				—
12	+++	+++	++	++	+++				
13	+++	+++	+	+	+++				—

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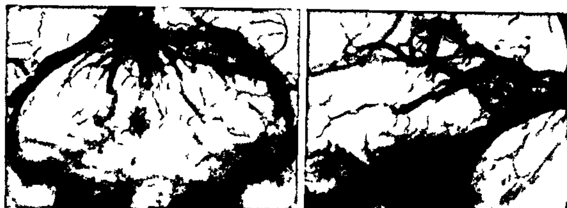


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Case No	Petrosal Draining Group D	Petrosal Draining Group n	Hemispheric Veins D	Hemispheric Veins n	Galenic Draining Group	Inf Vermian V D	Inf Vermian V	Precentral Vein	Ant Pont mesenc V
1	++	++	+++	+++	+++				
2	(+)	–	(+)	(+)	+	–		–	–
3	+	+	+	++	++			–	x
4	+++	++	+++	++	+++				
5	++	+	+++	+++	+++				–
6	+	(+)	(+)	–	–		x	–	–
7	+++	+++	+++	+++	+++				
8	+++	+++	+++	+++	+++				
9	+	+	++	++	+++	–			–
10	++	++	+++	+++	+++		–	–	
11	(+)	–	+	+	++				–
12	+++	+++	++	++	+++				
13	+++	+++	+	+	+++				–

Fig 5 Incidence and extent of filling in postmortem phlebography of the posterior fossa X = Veins filled by contrast medium – = *Veins not* filled by contrast medium Filling in separate areas graded from + + + = extensive to (+) = poor

PERESE D M Superficial veins of the brain from a surgical point of view J Neurosurg 17 (1960) 402

PLAUT H F Vertebral arteriography of the brain Amer J Roentgenol 74 (1955) 226

RODDA R A and DUGDALE L M The necropsy demonstration of carotid vertebral and cerebral artery disease in cases of cerebral infarct N Z med J 62 (1963) 510

STEIN B M McCORMICK W F RODRIGUEZ J N and TAVERAS J M Postmortem angiography of cerebral vascular system Arch Neurol 7 (1962) 545

STEPHENS R B and STILWELL D L Arteries and veins of the human brain Charles C. Thomas Springfield Illinois 1969

SVARE G T TAVERAS J M and STEIN B M Postmortem angiography of the cerebral vascular system Neurology 14 (1964) 1149

VANDER EECKEN H M and ADAMS R D The anatomy and functional significance of the meningeal arterial anastomoses of the human brain J Neuropath exp Neurol 12 (1953) 132

WOLF B S HUANG Y P and NEWMAN C M The lateral anastomotic mesencephalic vein and other variations in drainage of the basal cerebral vein Amer J Roentgenol 89 (1963) 411

WOLLSCHLAEGER G and WOLLSCHLAEGER P Arterial anastomoses of the human brain Acta radiol Diagnosis 5 (1966) 604

REFERENCES

BROWN B St J and TATLOW W F Radiographic studies of the vertebral arteries in cadavers Effects of position and traction on the head Radiology 81 (1963) 80

CORRALES M and MOLLER A Vascular displacements in intra and extra axial tumors of the posterior fossa To be published in Acta radiol Diagnosis

GALLOWAY J R and GREITZ T The medial and lateral choroid arteries An anatomic and roentgenographic study Acta radiol 53 (1960) 353

GILLOT C et AARON C Les possibilités de la phlébographie occlusive Étude anatomique et expérimentale Premiers résultats radio cliniques Bull Soc int Chir 23 (1964) 487

— — et CHASSAING P Étude radio anatomique du sinus caverneux et de ses voies de dérivation Arch Anat path 12 (1964) 113

GREITZ T CORRALES M and MOLLER A Stereotaxic methods in the investigation of experimentally produced intracranial displacements To be published in Acta radiol Diagnosi

— and SJOGREN S E The posterior inferior cerebellar artery Acta radiol Diagnosis 1 (1963) 284

HASSLER O (a) Venous anatomy of human hindbrain A stereomicroangiographic study of the venous angio architecture and the venous areas of drainage Arch Neurol 16 (1967) 401

— (b) Arterial pattern of human brainstem Normal appearance and deformation in expanding supratentorial conditions Neurology 17 (1967) 368

HAUGE T Catheter vertebral angiography Acta radiol (1954) Suppl No 109

HUANG Y P and WOLF B S The vein of the lateral recess of the fourth ventricle and its tributaries Roentgen appearance and anatomic relationships Amer J Roentgenol 101 (1967) 1

— — and OKUDERA T Angiographic anatomy of inferior vermian vein of cerebellum Acta radiol Diagnosis 9 (1969) 327

HUTCHINSON E C and YATES P O The cervical portion of the vertebral artery A clinico pathological study Brain 79 (1956) 319

JOHANSSON C The central veins and deep dural sinuses of the brain An anatomical and angiographic study Acta radiol (1954) Suppl No 107

JOHNSON R T and YATES P O Brain stem haemorrhages in expanding supratentorial conditions Acta radiol 46 (1956) 250

KAPLAN H A technique for anatomical study of the blood vessels of the brain Anat Rec 116 (1953) 507

— Arteries of the brain Acta radiol 46 (1956) 364

LILIEQUIST B The subarachnoid cisterns An anatomic and roentgenologic study Acta radiol (1959) Suppl No 185

LORENZ R Die Bedeutung der Phlebographie für die Tumordiagnostik des Gehirns Acta neurochir 1 (1951) 392

MANI R L NEWTON T H and GLICKMAN M G The superior cerebellar artery An anatomic roentgenographic correlation Radiology 91 (1968) 1102

MATSUDA M Post mortem cerebral angiography Iryo 18 (1964) 609

MOLLER A Vertebral angiography in fourth ventricle tumours To be published in Acta radiol Diagnosis

— and CORRALES M Vascular displacements in cerebellar tumors of different locations To be published in Acta radiol Diagnosis

MONIZ E Die cerebrale Arteriographie und Phlebographie *In* Handbuch der Neurologie Erganzbd 2 Julius Springer Berlin 1940

PERESE D M Superficial veins of the brain from a surgical point of view J Neurosurg 17 (1960) 402

PLAUT H F Vertebral arteriography of the brain Amer J Roentgenol 74 (1955) 226

RODDA R A and DUGDALE L M The necropsy demonstration of carotid vertebral and cerebral artery disease in cases of cerebral infarct N Z med J 62 (1963) 510

STEIN B M McCORMICK W F RODRIGUEZ J N and TAVERAS J M Postmortem angiography of cerebral vascular system Arch Neurol 7 (1962) 545

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ECTASIA OF CEREBRAL ARTERIES IN ACROMEGALY

by

A. HATAM and T. GREITZ

LERICHE (1925) observed at operation unusually long brachial and femoral arteries. In 1927 he reported diffuse cylindric and regular dilatation of the right and left colic arteries also seen at laparotomy. In 1942 he reported further observations on similar changes, which he considered due to a pathologic dilatation of the arteries other than aneurysms. The following year he suggested the name of dolichomega-arteries. In 1947 he published the first angiographic examination. He described these vascular changes to be present in various areas such as the iliac arteries, the femoral arteries and the popliteal arteries and stated that their cause was unknown. LEGER & CERBONNET (1950) found fusiform dilatation of the common carotid arteries at operation. GREITZ & LÖFSTEDT (1954) in an angiographic investigation of similar changes in the basilar artery, named this condition ectasia and suggested that these vascular changes were generalized. This was later confirmed by VON REIS & LÖFSTEDT (1954) and HULTÉN GYLLENSTEN et coll. (1959). GREITZ & LÖFSTEDT at microscopic examination found loss of elastic tissue and such changes were also reported by HULTÉN GYLLENSTEN et coll. The radiologic features of this disease have in later years been dealt with in a series of publications by HULTÉN GYLLENSTEN et coll. (1959), BARIÉTY et coll. (1961), WAREMBOURG et coll. (1963), CRISTI & DALBUONO (1965),

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Table 1

Clinical findings in 13 acromegalic patients

Patient No	Age	Sex	Clinical signs and symptoms duration	Blood pressure	Growth hormone level	Histologic diagnosis
1	24	♀	Acromegaly and amenorrhea 5 years diplopia 1 year left temp hemianopsia	130/ 90	Not determined	Eosinophilic adenoma
2	27	♂	Acromegaly 2 years bitemporal upper quadrantanopsia	120/ 80	Not determined	Eosinophilic adenoma
3	32	♀	Weight gain hypermenorrhea 5 years normal visual field	175/ 90	Elevated	Not verified
4	33	♀	Acromegaly 10 years left oculomotor paresis	175/ 90	Elevated	Esoinophilic adenoma
5	35	♀	Acromegaly headache 1 year bitemporal hemianopsia	130/ 80	Elevated	Mixed adenoma
6	42	♂	Acromegaly 10 years *impotence* 2 years bitemporal upper quadrantanopsia	140/ 80	Elevated	Not verified
7	43	♂	Acromegaly and headache 10 years bitemporal hemianopsia	155/110	Elevated	Mixed adenoma
8	50	♂	Acromegaly duration unknown normal visual field	155/ 80	Not determined	Eosinophilic adenoma
9	57	♀	Acromegaly 14 years left homonymous hemianopsia	205/110	Not determined	Not verified
10	58	♂	Acromegaly 5 years diplopia left third nerve palsy	140/ 90	Elevated	Not verified
11	61	♀	Acromegaly 20 years left temporal upper quadrantanopsia	185/115	Elevated	Not verified
12	63	♂	Acromegaly 10 years bitemporal hemianopsia	180/110	Not determined	Mixed adenoma
13	77	♂	Acromegaly 11 years bitemporal hemianopsia	130/ 75	Elevated	Mixed adenoma

WEIBEL & FIELDS (1965) DETTORI et coll (1966) STAPLE et coll (1966), ERTUGRUL (1967) ECOIFFIER et coll (1968) SACKS & LINDENBURG (1969) LEA THOMAS & ANDRESS (1970) among others The changes described are widening of the arteries and elongation resulting in tortuosity Another feature is the so-called kinking (AZAMBUJA et coll 1963 BOSTROM & GREITZ 1967) The latter authors showed the kinking to be invariably linked with the degenerative changes in the media as seen in ectasia

WAREMBOURG et coll. found one case of bilateral femoral dolichomega arteries in an acromegalic patient. In a search for a relation between pituitary tumor and dolichomega arteries, these authors found two cases of ectatic carotid arteries as revealed by cerebral angiography. They stated it would be logical to expect large and elongated arteries in acromegalic patients and attribute them to the dysfunction of the pituitary. Some observations of marked ectasia in acromegalic patients have prompted us to investigate the relationship between cerebral arterial size and acromegaly.

Material and Methods. All the patients with clinically verified acromegaly who were referred to Karolinska sjukhuset and who were examined with carotid angiography were included in the investigation (Table 1). The indication for angiography was cranial nerve involvement, generally a visual field defect. There were 13 patients, ranging in age from 24 to 77 years with a mean age of 46.3, 7 were males and 6 females with duration of symptoms varying from 1 to 20 years. With one exception all had either histologically proved eosinophilic (in 4 cases mixed, with eosinophilic cells predominating) adenoma or increased growth hormone level or both. All patients had an enlarged sella, in 12 it was balloon shaped, in 1 (Case 6) it was bowl shaped. In 10 patients suprasellar extension of tumor varying from 0.5 to 2 cm was seen at encephalography. In one case angiography was undertaken because of a recurrent tumor, in all other patients the angiography was performed before surgical intervention. Two patients had radiation treatment directed to the hypophysis a few years before the angiography (Cases 6 and 11).

All patients were submitted to selective carotid angiography. Three patients were examined by selective catheterization via the femoral route. The remainder were examined following direct puncture of the carotid artery in the neck. In 3 cases the injection was made into the common carotid artery, in 10 cases it was made into the internal carotid artery. Serial angiography both in a.p. and lateral projections was employed in all cases. The exposures were made at the rate of two films per second in the arterial phase. The contrast medium used was Isopaque Cerebral in 12 cases and Urografin 60 % in one case.

The diameters of the internal carotid and middle cerebral arteries were measured according to GABRIELSEN & GREITZ (1970). In each case one measurement from the extradural part of the internal carotid artery just proximal to its bend at the posterior aspect of the cavernous sinus (C_s) was made in the lateral projection. In addition to this measurement two others were made in the a.p. view, one from the internal carotid 5 mm proximal to its bifurcation (C) and one from the middle cerebral 5 mm distal to its origin from the carotid artery (M). Measurements were made independently by two observers (G. and H.). The difference between observed mean diameters ($\bar{y}$) and expected normal

Table 2

Angiographic measurements of internal carotid and middle cerebral arteries M C and C refer to diameters of middle cerebral and internal carotid arteries according to GABRIELSEN & GREITZ *(1970)*

Arterial diameters and their sum	Measured values (mean and range)	Expected normal values (mean and range)	Difference	t test for difference	Statistical significance
M	4 223 (3 0–4 8)	3 925 (3 69–4 24)	0 298	2 05	5
C	4 969 (4 2–6 2)	4 627 (4 42–4 91)	0 342	2 24	
C	6 677 (5 5–7 8)	6 195 (5 71–6 71)	0 482	2 18	5
M+C+C	15 797 (14 2–18 0)	14 742 (13 84–15 87)	1 055	2 78	1

values ($\bar{y}$) was subjected to a t test to judge its significance The t variable was obtained as $t = \frac{\bar{y} - \bar{y}c}{\sqrt{\sigma^2 y\ K}}$

The expected normal mean values were calculated according to the following formulas obtained by an analysis of the material of GABRIELSEN & GREITZ

$$\bar{y}c\mathrm{M} = 1\ 7834 + 0\ 1906\ X + 0\ 1179\ W$$
$$\bar{y}c\mathrm{C} = 2\ 8059 + 0\ 1797\ X + 0\ 0998\ W$$
$$\bar{y}c\mathrm{C} = 3\ 9147 + 0\ 6444\ X + 0\ 1122\ W$$
$$\bar{y}c(\mathrm{M}+\mathrm{C}+\mathrm{C}_s) = 8\ 5039 + 1\ 0146\ X + 0\ 3298\ W$$

where X denoted proportion of males in the material and W means average external biparietal diameters The value K in the denominator of the test variabel is a function of both X and W

Results

The measurements made by observers G and H were compared with those obtained in a material of normal patients examined earlier (GABRIELSEN & GREITZ) Part of this normal material was measured by observer H No systematic difference in the results obtained by the two observers was noticeable The statistical analysis was based on values of observer G

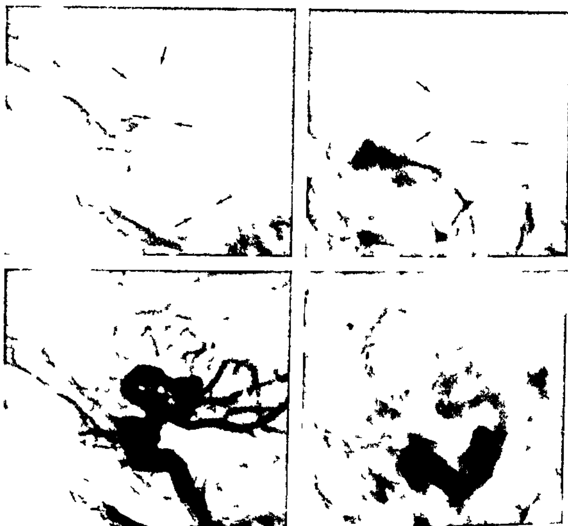


Fig. 1. Marked intracranial ectasia associated with extensive calcifications (→) of the vessel wall in an acromegalic patient.

The expected value of each individual measurement (M, C, C_5) and the sum of M, C and C_5 were compared with those obtained in each individual patient and were found to be above the expected value, with regard to M in 10 cases, with regard to C in 9 cases, with regard to C_5 in 8 cases and with regard to the sum of the measurements in 10 cases (Table 2). The expected mean values of the individual measurements M, C and C_5 calculated according to the above formula were all below the corresponding mean measured values, the difference being significant at the 5 per cent level. The similar difference for the sums of M, C and C_5 was significant at the 1 per cent level (Table 2). The length of the siphon ranged from 12 to 26 mm with an average of 16.6 mm as compared to 15.1 in the material of GABRIELSEN & GREITZ.



Fig 2 Marked extracranial ectasia in a 77 year old acromegalic male Fold produced by kinking indicative of the degeneration of the media occurring in arteriectasis (→) Carotid siphon and middle cerebral artery were found at operation to be constricted by the tumor

Although the results of measurements showed that the average values of arterial caliber were significantly increased, ectasia was found at inspection only in 8 patients In 6 cases it was marked (Figs 1, 2 3) In the younger individuals dilatation was more marked than elongation and tortuosity (Fig 4) The condition of the entire internal carotid artery in the neck could be evaluated in 9 patients and in 7 patients dilatation and tortuosity indicating ectasia were found Kinking (Fig 2) was present in 2 patients one of which without obvious dilatation of the vessel

Discussion

The external biparietal diameter in acromegalic patients being increased their expected arterial size is also greater than in normal individuals this fact tends to reduce the difference between measured and expected values and augments the probability of a real increase in arterial size One of the two patients whose sum of measurements were below the expected values did have ectasia but had constriction by tumor of internal carotid and middle cerebral arteries (Fig 2) which reduced the sum of measurements WAREMBOURG et coll




Fig. 3. Extra- and intracranial ectasia in a 50 year old male. Typical umbrella shape of the carotid siphon and its terminal branches.




Fig. 4. Wide internal carotid artery without obvious tortuosity in a 12 year old male.

suggested that ectasia is rare in patients with pituitary tumors. Our results indicate that dilatation of the cerebral arteries in fact is a common finding in individuals with eosinophilic adenomas and acromegaly. In our experience, chromophobe adenomas are not associated with arteriectasis to any larger extent than other conditions. In a series of measurements in 30 chromophobe adenomas no significant deviation from expected values of arterial diameter was found. It therefore seems reasonable to assume that the occurrence of ectasia in acromegaly is not a mere coincidence.

Acromegalic patients are known to have high blood pressure and hypertensive patients may be more prone to develop arteriectasis than normotensive patients. At least 6 of our patients were definitely hypertensive. However, no correlation between the dilatation of the arteries and blood pressure was noted. In fact, 2 of the patients with hypertension had no definite enlargement of the arteries. Therefore a more plausible explanation would be that the arteriectasis is part of the splanchnomegaly and hence governed by the growth hormone secretion. Of course, this does not in our opinion justify — at least not at the present stage — the assumption of arteriectasis as being always due to a hormonal dysfunction. To clarify this a comparison of the anatomic changes seen in acromegalics and other patients with ectasia would be of utmost interest.

Arteriectasis is known to occur more frequently in older age groups The mean age in our patients was only 46 3 years Therefore the age does not seem to explain our findings The only patient whose sum of measurements (M+C+C) did not exceed the expected values despite the lack of constriction by the tumor was more than 50 years of age

Ectatic cerebral arteries are known to produce compression of cranial nerves Dilatation of the carotid siphon could cause nasal visual field defect by encroachment on the lateral part of the chiasma and optic tract In our material there was no indication of cranial nerve compression due to ectasia The high incidence of visual field defects which were secondary to suprasellar exten ion is due to the fact these symptoms prompted the angiographic examination

Acknowledgement

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SUMMARY

Cerebral arterial sizes were measured in 13 acromegalic patients examined with carotid angiography Marked ectasia of cerebral vessels was found in 6 patients and in the remainder cerebral arteries were mostly wide The mean arterial caliber *expressed as the* sum of three diameters at different levels was significantly greater than the expected normal mean value The etiology and significance of these observations are discussed

ZUSAMMENFASSUNG

Die Grosse der Cerebral Arterien wurde bei 13 Patienten mit Acromegalie mittels Carotis Angiographie gemessen Bedeutende Ekta ien der cerebralen Gefasse wurden bei 6 Patienten gefunden und bei den ubrigen waren die Cerebral Arterien im allgemeinen weit Das mittlere arterielle Kaliber ausgedruckt als die Summe von drei Diametern von verschiedenen Niveaus war signifikant hoher als der erwartete normale mittlere Wert Die Atiologie und Bedeutung dieser Beobachtungen werden besprochen

RÉSUMÉ

Le diametre des artères cerebrales a ete mesure chez 13 malades acromegales examines par angiographie carotidienne On a trouve *une ectasie* marquee des vaisseaux cerebraux chez 6 malades et chez les autres les arteres cerebrales etaient le plus souvent larges Le cal bre arteri l moyen exprime comme la *somme de* trois diametres à differents niveaux est signifi ativement plus grand que la valeur moyenne normale prevue Les auteurs examinent l etiologie et l interet de ces observations



Fig. 3. Extra- and intracranial ectasia in a 50 year old male. Typical umbrella shape of the carotid siphon and its terminal branches.

Fig. 4. Wide internal carotid artery without obvious tortuosity in a 12 year old male.

suggested that ectasia is rare in patients with pituitary tumors. Our results indicate that dilatation of the cerebral arteries in fact is a common finding in individuals with eosinophilic adenoma and acromegaly. In our experience, chromophobe adenomas are not associated with arteriectasis to any larger extent than other conditions. In a series of measurements in 30 chromophobe adenomas no significant deviation from expected values of arterial diameter was found. It therefore seems reasonable to assume that the occurrence of ectasia in acromegaly is not a mere coincidence.

Acromegalic patients are known to have high blood pressure and hypertensive patients may be more prone to develop arteriectasis than normotensive patients. At least 6 of our patients were definitely hypertensive. However, no correlation between the dilatation of the arteries and blood pressure was noted. In fact, 2 of the patients with hypertension had no definite enlargement of the arteries. Therefore a more plausible explanation would be that the arteriectasis is part of the splanchnomegaly and hence governed by the growth hormone secretion. Of course, this does not in our opinion justify — at least not at the present stage — the assumption of arteriectasis as being always due to a hormonal dysfunction. To clarify this a comparison of the anatomic changes seen in acromegalics and other patients with ectasia would be of utmost interest.

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY II (DIRECTOR PROF I WICKBOM) SAHLGRENSKA SJUKHUSET GOTHENBURG SWEDEN

EXTRADURAL MENINGIOMAS

Report of two cases

by

M ROSENCRANTZ and S STATTIN

Intracranial meningiomas are usually closely connected with the dura mater which may be infiltrated to a varying extent these originally located subdurally may penetrate the dura and invade the surrounding bone In this way or by growing through the foramina and fissures of the base of the skull and the facial bones extracranial extensions may occasionally appear as the first manifestation of the intracranial tumour Certain cranial meningiomas extend mainly into the dura and the adjacent bone with only a relatively small intracranial portion such tumours may be designated dural and extradural The most common ones of this type are those meningiomas of the ridge of the sphenoid growing en plaque

Cranial meningiomas situated exclusively extradurally are uncommon Only 9 cases more or less extensively described were found in the literature and in all but one the tumour was located in the frontal region The growth in 3 cases involved the frontal bone and reached but did not infiltrate the underlying dura

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REFERENCES

AZAMBUJA, N., LENZI, A. y BOWARZINSKI, J.: Radiología de las deformaciones de la arteria carotida interna en el cuello. (In Spanish.) J. Rioplatense Radiologia (1963). Quoted by Weibel and Fields.

BARIETY, M., PAULET, J. et FERRIS, G.: Les dolicho méga artères. Bull. Soc. Méd. Paris 77 (1961), 394.

BOSTRÖM, K. and GREITZ, T.: Kinking of the internal carotid artery. A roentgenologic and histologic study. Acta radiol. Diagnosis 6 (1967), 105.

CRISTI, C. e DALBUONO, S.: Su di un caso di emispasmo facciale associato a mega-dolico vertebro basilare. (In Italian.) Nunt. radiol. *12 (1965), 1.*

DETTORI, P., CRISTI, C. e DALBUONO, S.: Anomalia megadolichobasilare. (In Italian.) Radiol. med. 52 (1966), 1259.

ECOIFFIER, J., LAVAL-JEANTET, M. et KAUFFMANN: Ciné artériographie fémorale dans les athéromatoses avec dolicho méga artère. J. Radiol. Électrol. 49 (1968), 294.

FERTUCRUI, A.: Diffuse tortuosity and lengthening of the arteries. Circulation 36 (1967), 400.

GABRIELSEN, T. O. and GREITZ, T.: Normal size of the internal carotid, middle cerebral and anterior cerebral arteries. *Acta radiol. Diagnosis 10 (1970), 1.*

GREITZ, T. and LOFSTEDT, S.: The relationship between the third ventricle and the basilar artery. Acta radiol. 42 (1954), 85.

HULTEN-CALLENSTEN, E. L., LOFSTEDT, S. and VON REIS, G.: Observations on generalised arteriectasis. Acta med. scand. 163 (1959), 125.

LEA THOMAS, M. and ANDREWS, M. R.: Phlebographic changes in arteriomegaly. Acta radiol. Diagnosis 10 (1970), 127.

LEGER, L. et CERBONNET, G.: Dolicho méga artère. Presse méd. 58 (1950), 951.

LERICHE, R.: Sur les lésions de l'adventice artérielle et sur certains états anormaux des grosses artères. Lyon chir. *22 (1925), 326.*

Dilatations cylindriques, diffuses et régulières, des artères coliques droites, de l'arcade de Riolan et de la colique gauche, de causes inconnues. Lyon chir. *24 (1927), 700.*

Dilatation pathologique des artères en dehors des anévrysmes, vie tissulaire des artères. Presse méd. 50 (1942), 641.

Dolicho et méga artère. Dolicho et méga veine. Presse méd. 51 (1943), 554.

Les symptomes douloureux des dolicho artères. Presse méd. 55 (1947), 641.

Dolicho méga artère bilatérale fémoropoplitée. Presse méd. 62 (1954), 1464.

VON REIS, G. och LOFSTEDT, S.: Allmän arteriektasi. (In Swedish.) Nord. Med. 51 (1961), 514.

SACKS, J. G. and LINDENBERG, R.: *Dolichoectatic intracranial arteries.* Johns Hopk. med. J. 125 (1969), 95.

STAPLE, T. W., FRIEDENBERG, M. J., ANDERSON, M. S. and BUTCHER, JR. H. R.: Arteria magna et dolicho of Leriche. Acta radiol. Diagnosis 4 (1966), 293.

WAREMBOURG, H., NIQUET, G., MERLEN, J. F. et coll.: Trouble de la circulation artérielle des membres inférieurs chez un acromégale. Lille méd. 8 (1963), 461.

— MERLEN, J. F. et coll.: Les dolichoméga artères. Lille méd. 8 (1963), 661.

WEIBEL, J. and FIELDS, S. J.: Tortuosity, coiling and kinking of the internal carotid artery. Neurology 15 (1965), 7.

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Cranial meningiomas situated exclusively extradurally are uncommon Only 9 cases more or less extensively described were found in the literature and in all but one the tumour was located in the frontal region The growth in 3 cases involved the frontal bone and reached, but did not infiltrate, the underlying dura

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(VASIONZII 1953, TRAUB 1961, TAVERAS & WOOD 1964) In one case it was firmly adherent to the inner table of the frontal bone and rested on the dura (FRAZIER & ALPERS 1933) The neoplasm in 5 cases arose from the external table, *connected with the periosteum of a temporal bone in one case and of a* frontal bone in 4 cases (ZACHARIAE 1952, PENDERGRASS & HOPE 1953, NUNES & FERNANDES 1954, SIEGEL & ANDERSON 1966, WAGA *et coll* 1970)

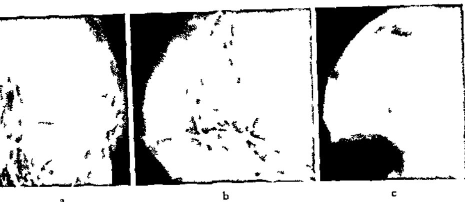
With the exception of the spinal canal (SINGH et coll 1968, FORTUNA et coll 1969, and others), which is excluded in this report, the orbit seems to be the most common site of extradural meningiomas (CRAIG & GOGELA 1949, BOURGEOIS & JOST 1955, BAGCHI & SEN GUPTA 1966, MACMICHAEL & CULLEN 1969, and others) When an intraorbital tumour has invaded the surrounding bony walls it is hardly possible to decide whether it is primary in the orbit or a propagation of an intracranial mass The cases reported suggest that some of them were intracranial meningiomas with secondary extension into the orbit *through the lamina cribrosa or the sphenoid About 10 cases remain in which it* appears as if the tumour grew primarily in the orbit

Other localisations of extradural, or as they have also been called ectopic, extracranial or extracalvarial, meningiomas were the following Frontal sinus in 6 cases (NEW & DEVINE 1947, CANCIULLO et coll 1963, LEROUX ROBERT et coll 1966, MAJOROS 1970), ethmoidal sinus in 3 cases (RUMPF 1958, LINDSTROM & LINDSTROM 1969, WAGA et coll 1970), maxillary sinus in 2 cases (SHAHEEN 1931, HILL 1962), nasal cavity in 4 cases (MADONIA & SIGNORELLI 1959, LEROUX ROBERT et coll 1966, BAGCHI & SEN GUPTA 1969, PATHAK 1969), cutis in 7 cases (*WINKLER 1904, ALKIEWICZ, BAIN & SHNITKA 1956*), subcutis in 2 cases (NEW & DEVINE 1947, KHANNA et coll 1961), and neck in 2 cases (HOYE et coll 1960, HALLGRIMSSON et coll 1970)

Tumours in the paranasal sinuses and the nasal cavity as with intraorbital meningiomas, may represent extensions of intracranial meningiomas

The cutaneous and subcutaneous meningiomas, 6 cases of tumours in the scalp near the midline and one case of three separate meningiomas in the dorsal paraspinal region, as well as those located to the neck, all seem to have had some relation to nerve sheaths or the spinal dura Extracranial metastases of meningeal tumours are known and reported to occur *in the lungs, lymph nodes* and liver (JUROW 1941, OPSAHL & LOKEN 1965, HAMBLET 1944, and others)

The preoperative radiologic examination in previously reported cases of extradural meningiomas has as a rule been only limited Angiography has thus been performed only in two cases (SIEGEL & ANDERSON 1966, LINDSTROM & LINDSTROM 1969) and the diagnosis as result of the microscopic examination seems to have come as a complete surprise The diagnostic difficulties may be illustrated by two cases, examined during the last two years



g 1 Case 1 a) b) Supraorbital bone lesion bulging outwards and intracranially c) Partly alcified mass filling up most of it is best demonstrated in lateral tomogram

Case Reports

Case 1 Male aged 26 with a tumour in the left frontal region from early childhood and bout a four month history of slight weakness of the right leg mainly on extension of the oot On admission a rounded hard tumour about 6 cm in diameter extending from the midline to about 2 cm lateral to the outer canthus of the eye with its lower border about 1 cm above the upper orbital margin was palpated The extensors of the right foot were weaker than those of the left Other neurologic findings and the EEG were normal

Roentgen examinations Within a fairly well demarcated area extending from the frontal sinus to the region of the pterion the left frontal bone had an irregular structure (Fig 1) The bone in this area was greatly expanded the lesion bulging outwards as well as intra cranially and into the adjoining sinus The upper orbital margin was slightly depressed The area was almost completely filled by a rounded mass the anterior part of which had the appearance of soft tissue while posteriorly adjacent to the markedly thinned internal table it was densely calcified The anterior bony wall was fairly thick though eroded from behind it had a rather peculiar structure with areas of broken trabeculation

Encephalography revealed that the left frontal horn was displaced about 1 cm posteriorly and somewhat flattened corresponding to the bone lesion Angiography of the left external carotid artery disclosed a slightly hypertrophic middle meningeal artery The anterior branch gave off many small tortuous arteries to the calcified posterior part of the rounded mass which was also supplied by another branch of the maxillary artery Contrast medium accumulated in the mass particularly evident in subtraction films (Fig 2) At angiography of the internal carotid artery arteries as well as veins were seen to run arched courses around the lesion The pericallosal artery was slightly displaced to the right Scanning revealed increased uptake of $^{99}Tc^{m}$ as well as of $^{87}Sr^{m}$ When at operation the frontal bone was broken up a peculiar cystic lesion appeared Within the cyst lay a solid rounded mass demarcated by a mucous membrane like structure and easily removed It was greyish yellow and had the consistency of hard rubber Bleeding rendered it impossible to determine the nature of the contents of the cyst It was somewhat questionable whether the thin posterior



Fig. 2. Case 1. Increased vascularity and accumulation of contrast medium in posterior part of the lesion at external carotid angiography (subtraction).

bony wall was part of the lesion or the wall of the sinus. The dura was pushed backwards but seemed to be intact.

Microscopy demonstrated the solid mass to be a typical psammomatous meningioma. The thin membrane covering the walls of the cystic parts of the lesion was made up of a fibrous stroma with areas of loose reticular and osteoid tissue interspersed. The marrow in the surrounding bone was partly replaced by connective tissue, poor in cells and with areas of newly formed non-lamellated bone. The compacta was in many places thinned and partly transformed into spongy bone. Microscopically these parts had an appearance similar to that evident in fibrous dysplasia of bone.

It was thus not possible to determine macro- or microscopically the origin of the tumour.

Case 2. Female, aged 40, with recurrent bilateral otitis and pain around the right ear for two months. Otologic examination disclosed an exudation in the right middle ear and diffuse swelling over the right zygomatic arch.

Roentgen examination, including tomography (Fig. 3 a, b), disclosed a soft tissue mass filling up the right half of the sphenoidal sinus and extending over the midline with a sharp rounded contour against the air in the left part of the sinus. The right lateral and anterior bony walls were extremely thin and in places probably eroded. Right internal carotid angiography (Fig. 3 c) revealed a small artery from the intracavernous portion of the internal carotid artery with tiny vessels in the center of the soft tissue mass. Transmaxillary sphenotomy was performed. The anterior wall of the sphenoidal sinus was in places extremely thin. When the sinus was opened a thick-walled cyst with highly viscous contents and partly filled by a semicompact mass like a granuloma was evident. A small defect was present superiorly in the posterior bony wall of the sinus when it had been evacuated.

At microscopy, the granuloma-like tumour proved to be a meningioma of the transitional type, growing into the mucous membrane.

Case 2 appears to be first one reported of a meningioma arising in the sphenoidal sinus.

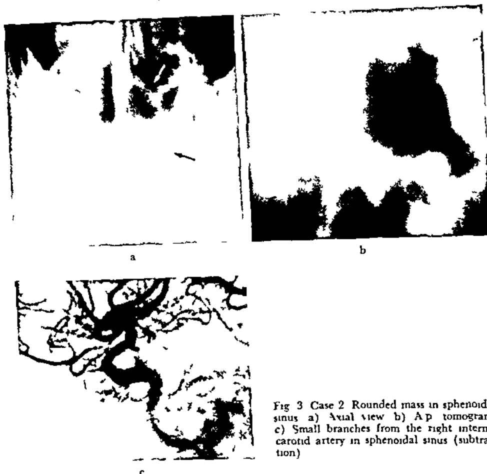


Fig 3 Case 2 Rounded mass in sphenoidal sinus a) Axial view b) A p tomogram c) Small branches from the right internal carotid artery in sphenoidal sinus (subtraction)

Discussion

Meningiomas are suppo ed to arise from cells of neuro-ectodermal origin the so-called cap cells or meningocytes which are found in the arachnoidea mainly at the tips of the arachnoidal villi Clusters of arachnoidal cells have al o been reported at the ites of emergence of cranial and spinal nerves from the dura mater in the heaths of nerves inside as well as outside the skull and even in the cranial periosteum Extradural meningiomas are thought to ari e from such cells as well as from ectopic arachnoidal tissue in some way incorporated in the cranial bones during their growth or protruding in the sutures during foetal life being trapped extracranially This could explain the most common sites near the midline of the frontal region and in the paranasal sinu es A relatively

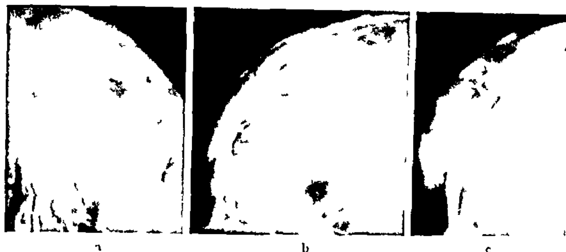


Fig. 4 a, b) Mixed type of fibrous dysplasia of left frontal bone and anteriorly in base of skull. c) Tangential view. The lesion does not bulge into the cranial cavity.

high incidence in younger age groups might also be evidence of a developmental disorder. The rare intracerebral and intraventricular meningiomas with no apparent connection with the dura could have a similar mode of origin.

The dura was macroscopically intact in Case 1 while a small defect was present in the wall of the sphenoidal sinus in Case 2. A connection with the dura was not sought and accordingly cannot be excluded. A really thorough search for such a connection was made in some of the earlier reported cases; in most of them it was found although in one case first at microscopy however (SIEGEL & ANDERSON 1966). It seems probable that many so called extradural meningiomas do have connections with the intracranial meninges.

Bone changes in the first case raised the possibility of a mucocele of the frontal sinus or fibrous dysplasia of bone though the increased vascularization was against the former. The mixed type of lesion, i.e. both sclerotic and lytic, of fibrous dysplasia frequently involves the vertical parts of the frontal bones (Fig. 4). The bone in typical cases is grossly thickened with decalcified areas alternating with areas of sclerosis. The inner table is usually not involved by the process, however, and it does not bulge into the cranial cavity. Fibrous dysplasia of the vault may be fairly well vascularized (LIN et coll. 1969, ROSENCRANTZ 1969) but accumulations of contrast medium as in our Case 1 have not been demonstrated.

The dural and extradural meningiomas of the sphenoid growing en plaque cause sclerotic thickening of the wings of the sphenoid and adjacent bones (Fig. 5 a). The main differential diagnosis lies with the sclerotic type of fibrous dysplasia (osteofibroma) and from the bone changes alone may be impossible



Fig 5 a) Meningoma of the wing of the sphenoid and adjacent bones growing en plaque b) Hypertrophic middle meningeal artery with branches to the sclerotic lesion (subtraction)

Both lesions grow slowly and are usually relatively asymptomatic they are therefore seldom subjected to surgery and a diagnosis is rarely obtained A few cases of verified meningiomas of this kind have had increased vascularization with typical vessels at angiography (Fig 5 b) As the authors have no knowledge of verified fibrous dysplasia of this localization examined angiographically they do not know if the lesions may be differentiated

These considerations suggest that extradural meningiomas should be borne in mind in lesions of the frontal bones the anterior base of the skull and the paranasal sinuses Angiography may be helpful and suggest the correct diagnosis

SUMMARY

Meningiomas growing exclusively extradurally presumably occurring as the result of a developmental disturbance are uncommon A survey of the literature is given and two cases of cranial extradural meningiomas probably arising in the paranasal sinuses are reported The differential diagnosis is discussed

ZUSAMMENFASSUNG

Meningeome die ausschliesslich extradural wachsen und vorwiegend als Ergebnis einer Entwicklungsstorung auftreten sind ungewohnlich Es wird eine Literaturubersicht gegeben und uber zwei Falle kranialer extraduraler Meningeome die wahrscheinlich in den Nasennebenhohlen entstanden sind berichtet Die Differentialdiagnose wird besprochen

RÉSUMÉ

Les méningiomes à développement exclusivement extradural résultant vraisemblablement d'un trouble du développement sont rares. Les auteurs font une revue de la bibliographie et présentent deux cas de méningiomes craniens extraduraux prenant probablement naissance dans les sinus de la face. Ils discutent le diagnostic différentiel.

REFERENCES

ALKIEWICZ, J. Cited by BAIN and SHNITKA.

BACCHI, A. K. and SEN GUPTA, K. P. A study of cranial meningiomas with special reference to those producing proptosis. Int. Surg. 46 (1966), 307.

— — Primary nasal meningioma. J. Indian med. Ass. 53 (1969), 286.

BAIN, G. O. and SHNITKA, T. K. Cutaneous meningioma (psammoma). Arch. Derm. 74 (1956), 590.

BOURGEOIS, R. et JOST, M. Un cas de méningiome orbitaire à forme ostéolytique. Ann. Oto-laryng. (Paris) 72 (1955), 810.

CANCIULLO, D., NUCCI, C. e FRANZONI, M. Su un caso di meningioma apparentemente primitivo del seno frontale. (In Italian.) Otorinolaring. ital. 32 (1963), 339.

CRAIG, W. McK. and GOGELA, L. J. Intraorbital meningiomas. Amer. J. Ophthal. *32 (1949),* 1663.

FORTUNA, A., CAMBACORTA, D. and OCCHIPINTI, E. M. Spinal extradural meningiomas. Neurochirurgia (Stuttg.) 12 (1969), 166.

FRAZIER, C. H. and ALPERS, B. J. Meningeal fibroblastomas of the cerebrum. Arch. Neurol. Psychiat. 29 (1933), 935.

HALLGRIMSSON, J., BJORNSSON, A. and GUDMUNDSSON, G. Meningioma of the neck. J. Neurosurg. 32 (1970), 695.

HAMBLET, J. B. Meningioma with metastases to liver. Arch. Path. 37 (1944), 216.

HILL, C. L. Meningioma of the maxillary sinus. Arch. Otolaryng. 76 (1962), 547.

HOYT, S. J., HOAR, C. S. and MURRAY, J. E. Extracranial meningioma presenting as a tumor of *the neck. Amer. J. Surg. 100 (1960), 486.*

JUROW, H. N. Psammomatous dural endothelioma (meningioma) with pulmonary metastasis. Arch. Path. 32 (1941), 222.

KHANNA, S. D., SINGH, G. and SAIGAL, R. K. Ectopic meningioma in an infant. Arch. Surg. 89 *(1964), 752.*

LEROUX-ROBERT, J., GUIOT, G., PAQUELIN, F. et PRACHE, H. La propagation des méningiomes dans le massif maxillo-facial. Ann. Oto-laryng. (Paris) 83 (1966), 617.

LIN, J. P., GOODKIN, R., CHASE, N. E. and KRICHEFF, I. I. The angiographic features of fibrous dysplasia of the skull. Radiology 92 (1969), 1275.

LINDSTROM, C. G. and LINDSTROM, D. W. On extracranial meningioma. Acta otolaryng. 68 (1969), 451.

MACMICHAEL, I. M. and CULLEN, J. F. Primary intraorbital meningioma. Brit. J. Ophthal. 53 (1969), 169.

MADONIA, T. e SIGNORELLI, S. Considerazioni anatomo-radiologiche e cliniche su un caso di meningioma delle fosse nasali. (In Italian.) Clin. otorinolaring. 11 (1959), 223.

MAJOROS, M. Meningioma of the paranasal sinuses. Laryngoscope 80 (1970), 640.

NEW, G. B. and DEVINE, K. D. Neurogenic tumors of nose and throat. Arch. Otolaryng. 46 (1947), 163.

NUNES M A e FERNANDES A M B Meningioma extra-craniano muito provavelmente primitivo (In Portuguese) Gaz méd port 7 (1954) 63
OPSAHL JR R and LOKEN A C Meningioma with metastases to cervical lymph nodes Acta path microbiol scand 64 (1965) 294
PATHAK P N Ectopic meningioma of the nose J Laryng 83 (1969) 1115
PENDERGRASS E P and HOPE J W An extracranial meningioma with no apparent intra cranial source Amer J Roentgenol 70 (1953) 967
ROSENCRANTZ M Widened vascular grooves in fibrous dysplasia of the skull Acta radiol Diagnosis 9 (1969) 95
RUMPF G Psammose Geschwulste im Nasennebenhohlengebiet Z Laryng Rhinol 37 (1958) 163
SHAHEEN H B Psammoma in the maxillary antrum J Laryng 46 (1931) 117
SIEGEL G J and ANDERSON P J Extracalvarial m ningioma J Neurosurg 25 (1966) 83
SINGH R COERKAMP G and LUYENDIJK W Spinal epidural meningiomas Acta neurochir (Wien) 18 (1968) 237
TAVERAS J M and WOOD E H Diagnostic neuroradiology Williams & Wilkins Co Balti more 1964
TRAUB S P Roentgenology of intracranial meningiomas Charles C Thomas Springfield Illinois 1961
WAGA S KAMIJYO Y NISHIKAWA M et coll Extracalvarial meningiomas Brain and Nerve (Tokyo) 22 (1970) 153
WINKLER M Über Psammome der Haut und des Unterhautgewebes Virchows Arch path Anat 178 (1904) 323
VYSLONZIL E Meningeom im Stirnbeinbereich Mschr Ohrenheilk 87 (1953) 59
ZACHARIAE L A case of extracranial primary meningioma Acta path microbiol scand 31 (1952) 57

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REFERENCES

ALEKSIEWICZ, J.: Cited by BAIN and SHNITKA.

BACCHI, A. K. and SEN GUPTA, K. P.: A study of cranial meningiomas with special reference to those producing proptosis. Int. Surg. 46 (1966), 307.

— —: Primary nasal meningioma. J. Indian med. Ass. 53 (1969), 286.

BAIN, G. O. and SHNITKA, T. K.: Cutaneous meningioma (psammoma). Arch. Derm. 74 (1956), 590.

BOURGEOIS, R. et JOST, M.: Un cas de méningiome orbitaire à forme ostéolytique. Ann. Oto-laryng. (Paris) 72 (1955), 810.

CANCIULLO, D., NUCCI, C. e FRANZONI, M.: Su un caso di meningioma apparentemente primitivo del seno frontale. (In Italian.) Otorinolaring. ital. 32 (1963), 339.

CRAIG, W. McK. and GOGELA, L. J.: Intraorbital meningiomas. Amer. J. Ophthal. 32 (1949), 1663.

FORTUNA, A., GAMBACORTA, D. and OCCHIPINTI, E. M.: Spinal extradural meningiomas. Neurochirurgia (Stuttg.) 12 (1969), 166.

FRAZIER, C. H. and ALLERS, B. J.: Meningeal fibroblastomas of the cerebrum. Arch. Neurol. Psychiat. 29 (1933), 935.

HALLGRIMSSON, J., BJORNSSON, A. and GUDMUNDSSON, G.: Meningioma of the neck. J. Neurosurg. 32 (1970), 695.

HAMBLET, J. B.: Meningioma with metastases to liver. Arch. Path. 37 (1944), 216.

HILL, C. L.: Meningioma of the maxillary sinus. Arch. Otolaryng. 76 (1962), 547.

HOYE, S. J., HOAR, C. S. and MURRAY, J. E.: Extracranial meningioma presenting as a tumor of the neck. Amer. J. Surg. 100 (1960), 486.

JUROW, H. N.: Psammomatous dural endothelioma (meningioma) with pulmonary metastasis. Arch. Path. 32 (1941), 222.

KHANNA, S. D., SINGH, G. and SAIGAL, R. K.: Ectopic meningioma in an infant. Arch. Surg. 89 (1964), 752.

LE ROUX ROBERT, J., GUIOT, G., PAQUELIN, F. et PRACHE, H.: La propagation des méningiomes dans le massif maxillo-facial. Ann. Oto-laryng. (Paris) 83 (1966), 617.

LIN, J. P., GOODKIN, R., CHASE, N. E. and KRICHEFF, I. I.: The angiographic features of fibrous dysplasia of the skull. Radiology 92 (1969), 1275.

LINDSTROM, C. G. and LINDSTROM, D. W.: On extracranial meningioma. Acta otolaryng. 68 (1969), 451.

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MADONIA, T. e SIGNORELLI, S.: Considerazioni anatomo-radiologiche e cliniche su un caso di meningioma delle fosse nasali. (In Italian.) Clin. otorinolaring. 11 (1959), 223.

MAJOROS, M.: Meningioma of the paranasal sinuses. Laryngoscope 80 (1970), 640.

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Fig 1 Fig 2

Fig 1 Boy aged 12 years Poor musculature Shortening of the forearms with valgus deformities of the knees and tarsi

Fig 2 Vertebral column The intervertebral spaces are wide for the age and the annular ossification centers are barely visible Deformity of the vertebral bodies evident

were present the radial heads were easily palpable and mobile Extension of the elbow joints was 10 flexion 110 supination 100 and pronation 70 *the forearms* were flattened in the a p views and the hands were in the intermediate positions Passive movements of the carpal and finger joints were normal No active extension of the left metacarpo phalangeal joints could be elicited and marked impaired function of the abductor longus and extensors of the thumb was apparent due to paresis of the *radial nerve* No sensory disturbances Valgus deformities of the knees of 20 and valgus deformity of the tarsus of 10 were present The gait was grossly normal

Some measurements of the child Height 142 cm weight 32 kg span 134 cm circumference of the head 54 cm Upper extremity Proximal segment 25 cm middle segment 19 cm (radius 20 cm) distal segment 17 cm Lower extremity Proximal segment 40 cm middle segment 33 cm distal segment 24 cm

Laboratory examinations Duodenal intubation amylase 321 Wohlgemuth units (norm 2 560—10 240) lipase 7.5 ml N/10 NaOH (*norm 10—12*) trypsin 2 0 ml N/10 NaOH norm 7 5—12 5) Trypsin stool test negative Faecal fat 45 % (norm 5—20) Leucocytes differential white count 6 900 mm³ Neutrophils 30 % lymphocytes 60 % monocytes 9 % eosinophils 1 %) The neutropenia was inconstant Oral glucose tolerance test flat All other laboratory investigations including routine blood and urine examinations blood platelet bleeding and clotting time serum electrophoresis and electrolytes sweat chloride and

FROM THE ORTHOPAEDIC AND ROENTGEN DEPARTMENTS OF THE PEDIATRIC INSTITUTE OF THE MEDICAL ACADEMY, POZNAN, POLAND

UNUSUAL BONE CHANGES IN EXOCRINE PANCREAS INSUFFICIENCY WITH CYCLIC NEUTROPENIA

by

K. FELLMAN, K. KOZLOWSKI and A. SENGER

Congenital pancreatic insufficiency with cyclic neutropenia is a rare condition so that the occurrence of a case with unusual bone changes would appear to warrant publication.

Case report

A boy aged 12 years, was admitted with progressive elbow deformities and partial and progressive left forearm and hand paresis. He was a second child with no family history of interest. Weight at birth 3 100 g. General physical development was slow in the early years and was associated with the passage of bulky offensive stools two to three times a day. He learned to walk by eighteen months; his weight at two years was 10.5 kg. Exocrine pancreas insufficiency was finally diagnosed when the child was seven. Since that time he had received pancreatin and the stools had visibly improved although in his ninth year the mother noticed growing deformities of the elbows and two years later progressive partial paresis of the left forearm and hand appeared.

Condition on admission. Poor musculature, slight kyphoscoliosis and a rachitic rosary were evident (Fig. 1). The changes in the upper extremities were symmetric. Valgus deformities of the elbows of 20° with bulging of the radial heads and shortening of the forearm

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ulna (Fig 3) The vertebral bodies were somewhat flattened and the intervertebral spaces increased The lower thoracic and upper lumbar vertebrae were higher anteriorly than posteriorly with the reverse obtaining for the vertebral disks (Fig 2) The epiphyses of the long bones were also flattened but these changes were more marked distally than proximally The upper femoral and humeral epiphyses were within the normal range Only minimal changes were evident in the metaphyses of the long bones and were best seen in the hands (Fig 4) The skull appeared normal The left radial head was removed and treatment with pancreatin instituted

Control The patient was re examined eight months later His height was 150 cm and weight 38 kg The left lower arm and hand pareses were now normal but the patient complained of pain in the knees Roentgen examination disclosed that the valgus deformities of the knees had increased and some metaphyseal changes were present in the right lower femoral metaphyses

Discussion

Pancreatic insufficiency and blood disorders with metaphyseal dysplasia is a recognized syndrome but the bone lesions of the present case were quite different from those previously described (1, 2 3 4 6 7 8) They were characterised by generalised osteoporosis impaired tubulation of the long bones shortening of the fibulae and ulnae with subluxation of the radial heads Slight deformities of the epiphyses and the vertebral bodies with minimal or doubtful metaphyseal changes mostly in the distal parts were present These abnormalities resembled more the spondylo-epiphyseal dysplasia of the type that mostly affects the elbow joints or one of the forms of mesomelic dysplasia (MAROTEAUX et coll 1968) It is difficult to understand why the metaphyses were so little involved more detailed knowledge concerning the pancreatic juice in patients with pancreatic insufficiency might possibly have offered a solution The investigation indicated acinar dysfunction of a pancreas — all enzymes in the pancreatic juice were low but tubular function of the gland as measured by volume and a bicarbonate after stimulation with pancreozymin and secretin was not recorded Any causal relationship between pancreatic dysfunction and the skeletal abnormality present in the case reported is not obvious whether the complex of bone lesions was part of a new variety of the syndrome of pancreatic insufficiency or a mere fortuitous finding is thus not clear

SUMMARY

The case of a boy with exocrine pancreas insufficiency and cyclic neutropenia who also had unusual bone changes is described These consisted in particular of general osteoporosis and subluxation of the radial heads The possibility is not excluded that two different unrelated entities — exocrine pancreatic insufficiency with cyclic neutropenia and a variety of spondylo-epiphyseal dysplasia or mesomelic dysplasia — were present in the same patient

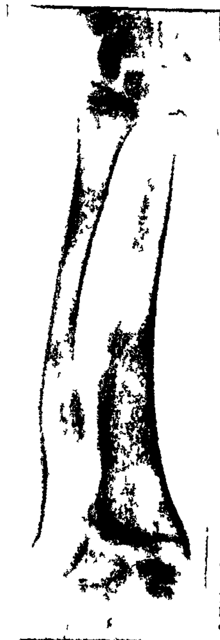


Fig. 3



Fig. 4

Fig. 3. Broadening and deformation of the upper part of the shortened ulna. The proximal part of radius has an S deformity with lateropalmar subluxation.

Fig. 4. Some shortening and decreased tubulation of the long bones, particularly the first metacarpal bone. The epiphyseal ossification centers are somewhat flattened and the metaphyses slightly irregular. Bone age normal.

sodium, cholesterol and alkaline phosphatase were within normal limits. EMG: Neurogenic lesion of m. extensor digiti sinistri.

Roentgenography. Generalised osteoporosis, most marked in the long bones and spine; decreased tubulation of the long bones and radial subluxation; the decreased tubulation was most obvious in the forearm bones and in the legs, particularly in the ulna and fibula which were also shortened; the radial subluxation was the result of the short deformed

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ZUSAMMENFASSUNG

Es wird uber einen Jungen mit insuffizienter Ausscheidung von Pankreassaft und zyklischer Neutropenie, gepaart mit ungewohnlichen Knochenveranderungen berichtet Die letzteren ausserten sich als allgemeine Osteoporose und als Subluxation des Radiuskopfes Die Moglichkeit, dass es sich hier um das zufallige Zusammentreffen von zwei verschiedenen Krankheitsbildern handelt kann nicht ausgeschlossen werden

RÉSUMÉ

Presentation du cas d un garçon qui avait une insuffisance pancreatique exocrine et une neutropenie cyclique avec des lésions osseuses inhabituelles Ces lesions consistaient en particulier en une osteoporose generalisee et une subluxation des tetes radiales Il n est pas exclu que deux maladies différentes sans liens entre elles — insuffisance pancréatique exocrine avec neutropenie cyclique et une variete de dysplasie spondylo epiphysaire ou de dysplasie mesomelique — aient ete presentes chez le meme malade

REFERENCES

1 Anderson C M Intestinal malabsorption in childhood Arch Dis Childh 41 (1966) 571

2 Bodian M Shirldon W and Lightwood R Congenital hypoplasia of the exocrine pancreas Acta paediat 53 (1964) 282

3 Burke V Colebatch J H Anderson C M and Simons M J Association of pancreatic insufficiency and chronic neutropenia in childhood Arch Dis Childh 42 (1967) 147

4 Giedion A Prader A Hadorn B et coll Metaphysare Dysostose und angeborene Pankreasinsuffiziens Fortschr Rontgenstr 108 (1968) 51

5 Maroteaux P Wiedemann R Spranger J et coll Essai de classification des dysplasies spondyloépiphysaires Simep Lyon 1968

6 Saint Martin J Fournet J P Charlas J et coll Insuffisance pancréatique externe avec granulopénie chronique Arch franç Pédiat 26 (1969) 861

7 Shmerling D H Prader A Hitzig W et coll The syndrome of exocrine pancreatic insufficiency neutropenia metaphyseal dysostosis and dwarfism *Helv paediat Acta* 24 (1969) 547

8 Taybi H Mitchell A D and Friedman G D Metaphyseal dysostosis and the associated syndrome of pancreatic insufficiency and blood disorders *Radiology* 93 (1969) 563

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ROENTGENOLOGIC EXAMINATION OF THE LARYNX

A clinical comparison

by

ANDERS HEMMINGSSON

The methods of treatment of malignant laryngeal lesions have changed considerably during the last two decades. Partial laryngectomy, which means that laryngeal function is to some extent preserved, is thus performed nowadays as hemilaryngectomy in the case of neoplasm limited to the vocal cords and as subtotal supraglottic laryngectomy in supraglottic tumours not involving the cord. The frequency of recurrence and the survival time are the same for these operations as for total laryngectomy (PEREZ et coll. 1968, OGURA & BILLER 1969). Good results are also obtained from radiation therapy in, for example, growths confined to the vocal cords. The exact localization and extent of the laryngeal lesion should be determined so that the best therapeutic method may be chosen. If radiation therapy is to be given, the location and size of the treatment field must be selected with precision.

This evaluation cannot be made solely clinically, including direct laryngoscopy; this may result in erroneous classification of the tumour before operation in approximately 20 per cent of cases (OGURA et coll. 1960 and LANDMAN 1970). It is mainly the caudal extent of the lesion that is difficult to evaluate in vocal cord and subglottic tumours. Subglottic dissemination thus escaped detection at laryngoscopy in about 80 per cent of cases in a series reported by MARTENSSON (1967) and at laryngoscopy combined with tomography — which

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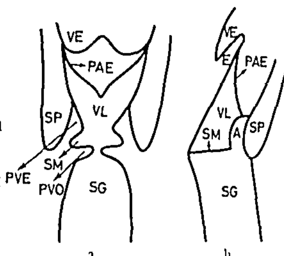


Fig. 1. The larynx in frontal (a) and lateral (b) projection. VE = vallecula epiglottica. E = epiglottis. PAE = plica ary-epiglottica. VL = vestibulum laryngis. PVE = plica ventricularis (false vocal cord). SM = ventriculus laryngis (sinus of Morgagni). PVO = plica vocalis (true vocal cord). SP = sinus piriformis. SG = subglottic area. A = arytenoid.

is the most usual roentgen method of examination of the larynx — in about 50 per cent. The clinical examination has improved since that time through the use of improved laryngoscopes and by the introduction of transcomoscopy via the cricothyroid membrane as described by MÅRTENSSON. The clinical examination must however always be combined with radiographic examination for adequate evaluation of laryngeal lesions (BRINDLE & STELL 1968, LANDMAN 1970, among others).

The methods of examination vary from ordinary radiography with different techniques to tomography and examination with a positive contrast medium. RETHI (1912) and WALDAPFEL (1938) suggested that a small film should be placed in the hypopharynx and exposed a.p. so as to eliminate interference from the cervical vertebrae. LINDGREN (1939) and YOUNG (1940) recommended a short focus film distance combined with a short object film distance and a p.a. beam direction for attainment of the greatest possible unsharpness of the vertebral column with retention of sharpness of the laryngeal structures. KOVACS (1960, 1961, 1964) was in favour of oblique projections for elimination of the interfering skeletal structures. A high potential technique in the frontal projection was used by SCHOEN (1953), McDONNELL et coll. (1958), MAGUIRE et coll. (1965), MAGUIRE (1966), and others, and was combined by VIGNAUD-PASQUIER et coll. (1963) and CHIESA & CARISANO (1967) with subtraction between roentgenograms taken during respiration and phonation.

Tomography has become a well established method since it was first described for laryngeal examination by LEBORGNE (1936), and is still the most common technique for examination of the larynx in the frontal projection in combination with ordinary radiography in lateral views.

Table 1

Techniques in the different methods of examination

	Ordinary radiography		Tomography	Laryngography		Cinematography	
	p.a.	lateral	a.p.	p.a.	lateral	p.a.	lateral
Focal spot	0.6 mm	0.6 mm	1.2 mm	0.6 mm	0.6 mm	0.6 mm	0.6 mm
Inherent filtration	1.5 mm Al	1.5 mm Al	1.8 mm Al	1.5 mm Al	1.5 mm Al	1.5 mm Al	1.5 mm Al
Extra filtration	1 mm brass	—	—	1 mm brass	—	—	—
Tube potential	150 kV	130—150 kV	140—150 kV	150 kV	130—150 kV	80—90 kV	50—60 kV
Anode current	160—320 mA	~160 mA	10—60 mA	160—320 mA	~160 mA	80 mA	80 mA
Exposure time	0.013—0.020 s	0.003—0.006 s	0.4—1.0 s	0.013—0.020 s	0.003—0.006 s	0.003 s	0.003 s
Film focus distance	~70 cm	~100 cm	140 cm	~70 cm	~100 cm	~100 cm	~100 cm
Object film distance	10—15 cm	30—40 cm	~20 cm	10—15 cm	30—40 cm	30—40 cm	30—40 cm
Grid ratio	—	—	7	—	—	—	—
Intensifying screens	Diamond (Siemens)	Diamond	Multisection cassette (Siemens)	Diamond	Diamond	—	—
Film	Kodak RP X Omat	Kodak RP X Omat	Kodak RP X Omat	Kodak RP X Omat	Kodak RP X Omat	Scopix G (Agfa Gevaert)	Scopix G (Agfa Gevaert)

During the last two decades radiographic examination of the larynx with a positive contrast medium — laryngography — has become increasingly common. This method was recommended by LINDGREN (1939) and FARINAS (1942) among others as a complementary examination in necessary cases. Laryngography in its present form was developed by POWERS et coll. (1957, 1961, 1964).

OGURA et coll. (1960), MEDINA et coll. (1961) and HOLTZ et coll. (1963) in association with the introduction of partial laryngectomy, and it has also been combined with tomography (BRAUER 1955) and cinematography (SCHUERMANS & BROMBART 1958, KERCHNER et coll. 1960, and others).

No systematic comparison of the diagnostic values of the different methods appears to have been made previously, with the exception of an investigation in which ordinary radiography with a high potential technique was compared with laryngography by THORNBURY & LATOURETTE (1967), in a series of 15 cases of laryngeal tumours. Refinement of the therapeutic technique has increased the demand for an exact diagnosis and it is therefore of importance to find out which roentgenologic method produces the best results. A comparison was therefore carried out between tomography and ordinary radiography with a high potential technique and including subtraction and laryngography with and without cinematography.

The roentgenologic anatomy of the larynx is presented in Fig. 1. Detailed descriptions of the roentgenologic anatomy and pathology of the larynx have been given by LINDGREN (1939), POWERS et coll. (1957, 1961), MEDINA et coll. (1961), HOLTZ et coll. (1963), BRINDLE (1966), PEREZ et coll. (1968) and LANDMAN (1970) among others, and these will not therefore be reviewed in this paper.

Technique. Ordinary radiography was performed in the p.a. and lateral projections with a high potential technique, the technical data of which appear in Table I. As in the other methods of examination, the ordinary radiography was performed during respiration and expiratory and inspiratory phonation. Subtraction between frontal roentgenograms obtained during quiet respiration and phonation was performed as screening by means of a Minusca Subtraction Apparatus (Oude Delft); photographic subtraction was also carried out in doubtful cases. The a.p. tomographic examination was performed with an MT 2 (Philips) apparatus linear in the longitudinal direction of the neck. An exposure angle of 14° and an exposure time of 1 s were used in 36 cases and 20° and 0.4 s in the remainder. A multisection cassette with 7 films at constant distances of 0.5 cm was used.

Laryngography was performed by the technique of POWERS et coll. (1957) after premedication with 1 mg atropine subcutaneously about 30 min before the examination for suppression of mucous secretion and the prevention of laryngospasm. With the patient sitting the larynx and pharynx were anaesthetized with xylocaine 4 % in spray form and as a solution instilled with a curved laryngeal syringe. About 10 to 15 ml of the contrast medium aqueous Dionosil were then instilled, again by means of a curved laryngeal syringe, without inspection of the larynx and the examination continued as in ordinary

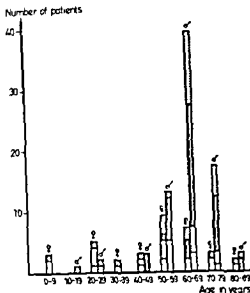


Fig 2 Distribution of 112 cases by age sex and diagnosis White area normal (19 cases) dotted area paresis (16 cases) black area tumour (45 cases) dashed area cord [illegible] (32 cases)

radiography Cinematography with positive contrast medium was then performed in the frontal and lateral projections at 30 frames per second A 9 image intensifier (Siemens) was used in conjunction with a 35 mm camera (Arriflex)

Tomography with contrast medium was carried out in only a few cases both for reasons of time and in consideration of the radiation hazard This technique was therefore not included in the comparative investigation

The laryngeal structures should not be masked by parts of the cervical spine e g spinous processes in frontal radiography This can be avoided by TV monitoring or fluoroscopy

An examination by ordinary lateral radiography with a tube potential of about 60 kV was performed for evaluation of the laryngeal cartilages In addition an examination during expiration against a closed nose and mouth (Valsalva manoeuvre) and with straining against the closed glottis was carried out with ordinary radiography and with laryngography and cinematography for evaluation of the motility of the structures surrounding *the larynx* mainly the hypopharynx These films which did not influence the results of the evaluation of the laryngeal structures were not included in the comparison between the different methods The different roentgenologic examinations were carried out within three days and as a rule on the same day

Material The investigation comprised 112 consecutive cases examined on 119 different occasions during the period September 1968 — November 1970

OGURA et coll. (1960), MEDINA et coll. (1961) and HOLTZ et coll. (1963) in association with the introduction of partial laryngectomy, and it has also been combined with tomography (BRAUER 1955) and cinematography (SCHUERMANS & BROMBART 1958, KERCHNER et coll. 1960, and others).

No systematic comparison of the diagnostic values of the different methods appears to have been made previously, with the exception of an investigation in which ordinary radiography with a high potential technique was compared with laryngography by THORNBURY & LATOURETTE (1967), in a series of 15 cases of laryngeal tumours. Refinement of the therapeutic technique has increased the demand for an exact diagnosis and it is therefore of importance to find out which roentgenologic method produces the best results. A comparison was therefore carried out between tomography and ordinary radiography with a high potential technique and including subtraction and laryngography with and without cinematography.

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Laryngography was performed by the technique of POWERS et coll. (1957) after premedication with 1 mg atropine subcutaneously about 30 min before the examination for suppression of mucous secretion and the prevention of laryngospasm. With the patient sitting the larynx and pharynx were anaesthetized with xylocaine 4 % in spray form and as a solution instilled with a curved laryngeal syringe. About 10 to 15 ml of the contrast medium aqueous Dionosil were then instilled, again by means of a curved laryngeal syringe, without inspection of the larynx and the examination continued as in ordinary

Table 2

Classification of the tumour cases

Stage	Site			
	Laryngeal tumours			Meso- and hypopharyngeal tumours
	Supraglottic	Glottic	Subglottic	
Benign	0	0	1*	2
Malignant T1	0	14	0	8
T2	0	1	0	
T3	2	15	0	
T4	1	0	1	
Total	3	30	2	10

* Chondroma

One epiglottic cyst in vallecula epiglottica and one hypopharyngeal polyp

Table 3

Number of normal and pathologic cases in which correct evaluation was possible with the different combinations of methods P, T, I and C (percentage and absolute figures)

Method	Diagnosis				Total
	Normal	Paresis	Tumour	Oedema/fibrosis	
P	89 (17/19)	100 (16/16)	53 (27/51)	76 (25/33)	71 (85/119)
T	100 (17/17)	100 (16/16)	35 (18/51)	62 (21/33)	62 (72/117)
I	89 (17/19)	100 (16/16)	86 (44/51)	91 (30/33)	90 (107/119)
C	100 (19/19)	94 (15/16)	83 (37/45)	92 (23/25)	89 (93/104)

The oedema/fibrosis group comprised 22 cases with laryngitis, 5 with post-traumatic bleeding or fibrosis of the larynx, 1 with vocal cord synechia and 5 cases with laryngeal or tracheal stenosis following prolonged endotracheal intubation.

Ordinary radiography and laryngography were carried out in all 119 cases; in 2 cases of infants 1 and 3 weeks old, tomography was not possible. Cinematography was performed in 104 of the 119 cases.

The distribution by age, sex and diagnosis appears in Fig 2 The diagnoses were verified by histologic examinations of biopsy material taken at direct laryngoscopy The tumours were classified according to the recommendations of UICC (1968) (given below) from the findings at direct laryngoscopy and at histologic examination of biopsy material near to the time of the radiographic examination (cf Table 2)

The larynx is divided into the following anatomic regions and sites in the T — Primary tumour group

Regions	*Sites*
Supraglottic	Posterior surfaces of the epiglottis excluding the tip of the epiglottis and the aryepiglottic fold (marginal zone) Arytenoid Ventricular cavities
Glottic	Vocal cords Anterior commissure Posterior commissure
Subglottic	

Supraglottic	*Glottic*	*Subglottic*
T1—Tumour confined to one anatomic site within the larynx		
Tumour confirmed to laryngeal *surface of epiglottis or* to an aryepiglottic fold or to a ventricular cavity or a *ventricular band*	Tumour confined to one *vocal cord and mobility of* cord remains normal	Tumour limited to one side of the subglottic region exclusive of the under surface of cord
T2—Tumour confirmed to one anatomic region within the larynx		
Tumour involving the epiglottis extending to the ventricular cavities or bands	Tumour involving both cords with normal mobility of one or both cords with fixation of cords	Tumour extending to two sides of subglottic region exclusive of the under surface of cords
T3—Tumour extending beyond one anatomic region but confined to the larynx		
Tumour of the epiglottis and/or ventricles or ventricular bands and extending into the cords	Tumours extending from cords either to subglottic region i e to ventricular region or to supraglottic bands or ventricles	Tumour involving the subglottic region and *extending* to the cords
T4—Tumour extending beyond the larynx		
Tumour as in *T1 T2 or* T3 but with direct extension to piriform sinus postcricoid region *vallecula or* base of tongue	*Tumour as in T1 T2 or T3* but with direct extension through cartilage to skin to *the piriform sinus* or to the postcricoid region	Tumour as in T1 T2 or T3 but with direct extension to trachea skin or postcricoid region

Table 4 (cont.)

Frontal				Lateral			
Subglottic region				All laryngeal structures			
N	Pa	Tu	C	N	P	Tu	C
100 (19/19)	100 (16/16)	98 (50/51)	97 (3[illegible]/33)	100 (19/19)	100 (16/16)	63 (32/51)	91 (30/33)
100 (17/17)	*100* (16/16)	96 (49/51)	97 (32/33)	—	—	—	—
100 (19/19)	100 (16/16)	98 (50/51)	100 (33/33)	*100* (19/19)	*100* (16/16)	[illegible]	*100* (33/33)
100 (18/18)	100 (16/16)	93 (42/45)	100 (25/25)	100 (18/18)	100 (16/16)	96 * (43/45)	*100* (2[illegible])

No difference in the results was obtained between examination with tomographic angles of 44° and of 20°

Normal cases Normal adult cases (n = 17) could be evaluated with all methods In two infants 1 and 3 weeks old, where only the method combinations P L and C were used the structures in the frontal projection could be determined only by cinematography (Table 4)

Paralysis of recurrent laryngeal nerve The structures could be defined by all methods in cases of paralysis of the recurrent laryngeal nerve (n = 16) Cinematography failed however in one case in which the contrast coating of the vocal cords was poor (Tables 3 4)

Tumours Correct evaluation of the laryngeal structures and of the localization and extent of the tumour was possible in 53 35, 86 and 83 per cent of the cases *respectively* (n = 51) (Table 3)

Of the methods comprising combination P it was mainly ordinary lateral radiography that failed to outline the structures correctly (evaluation possible 63 per cent) this also occurred in a relatively large number of cases with the false and true vocal cords and the laryngeal ventricle in the frontal projection (evaluation possible 78 per cent) (Table 4) The reason that the figure for these evaluation not possible cases is greater than that for combination P according to Table 3 is that some cases are included in both methods of combination in the frontal and lateral projections

Table 4

Number of cases in which a correct evaluation of the normal laryngeal structures and pathologic lesions in the larynx was possible by the different methods in frontal and lateral projections (percentage and absolute figures) (N = normal Pa = paresis Tu = tumour O = oedema/fibrosis)

Projection	Frontal							
Structures	Vestibulum laryngis plica aryepiglottica arytenoid				Plica ventricularis ventriculus laryngis plica vocalis			
Diagnosis	N	Pa	Tu	O	N	Pa	Tu	O
Ordinary radiography including subtraction	89 % (17/19)	100 % (16/16)	86 % (44/51)	97 % (32/33)	89 % (17/19)	100 % (16/16)	78 % (40/51)	79 % (26/33)
Tomography	100 % (17/17)	100 % (16/16)	86 % (44/51)	97 % (32/33)	100 % (17/17)	100 % (16/16)	57 % (29/51)	67 % (22/33)
Laryngography	100 % (19/19)	100 % (16/16)	98 % (50/51)	100 % (33/33)	89 % (17/19)	100 % (16/16)	90 % (46/51)	91 % (30/33)
Cinematography	100 % (18/18)	100 % (16/16)	96 % (43/45)	100 % (25/25)	100 % (18/18)	94 % (15/16)	89 % (40/45)	92 % (23/25)

No complications resulted from any of the different forms of examination

Method Combinations of the methods of ordinary frontal radiography, including subtraction, and ordinary lateral radiography (P), frontal tomography and ordinary lateral radiography (T), frontal and lateral laryngography (L) and frontal and lateral cinematography (C) were compared in evaluation of all normal and pathologic cases (Table 3) All normal structures in the larynx as well as the localization and extent of any lesions had to be defined and evaluated correctly for a case to be classified as evaluation possible If these criteria were not fulfilled the case was classified as evaluation not possible' An analysis was also made to determine which structures in the larynx were most difficult to evaluate according to the above criteria, and the different methods were divided into frontal and lateral projection methods (Table 4)

Finally the question of whether the different combinations of methods were complementary to one another or whether one single combination offered the best chance of correct evaluation was investigated

Results

A correct evaluation of the normal structures of the larynx and of the localization and extent of a lesion with the different forms of examination was possible in 71, 62, 90 and 89 per cent of the cases respectively (Table 3) Only in one case did subtraction radiography improve the possibility of evaluation



Fig 4 Left recurrent laryngeal nerve paralysis Frontal tomography during expiratory (a) and inspiratory (b) phonation and respiration (c) The right ventricle seems to be obliterated in (a) but widely dilated and free in (b)

remain These were examined by all method combinations with the exception of 2 cases in which C was not used On the basis of findings at direct laryngoscopy positive contrast examinations in 4 of these 7 cases provided information for a correct evaluation

Oedema/fibrosis Correct evaluation was possible in 76 by P in 62 by T in 91 by L and 92 per cent by C respectively of cases of oedema/fibrosis (n = 33) (Table 3) It was mainly the false and true vocal cords and the laryngeal ventricle in these cases also that were most difficult to evaluate by all methods

The 33 cases were examined by all methods except C which was not used in 8 cases Of the 33 cases evaluation was possible in 25 by P, 21 by T 30 by L and 23 by C (Fig 3b) The different methods were complementary to one another so that of the three cases in which evaluation was not possible by the L two could be evaluated by the T combination The lumen of the larynx was in these latter diminished due to post traumatic bleeding and fibrosis respectively and the contrast coating of the vocal cords at laryngography was poor The third case in which no correct evaluation was possible by any of the methods had chronic laryngitis

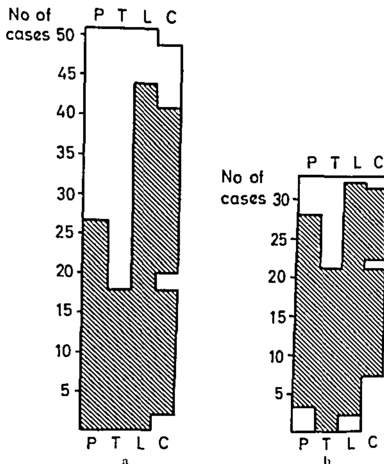


Fig. 3. Evaluation of a) 51 cases of tumour and b) 33 cases of oedema/fibrosis with the method combinations P, T, L and C. Each individual case has the same position throughout in the horizontal plane for P, T, L and C. □ = correct evaluation not possible. ▨ = correct evaluation possible.

The true and false vocal cords and the laryngeal ventricle were the most difficult to evaluate correctly by frontal tomography in combination T (evaluation possible, 57 per cent) and the laryngeal structures in ordinary lateral radiography as in combination P (Table 4). Similarly in combinations L and C it was the true and false vocal cords and the laryngeal ventricle that most often failed to be evaluated correctly in the frontal projection (90 and 89 per cent evaluation possible, respectively), (Table 4).

The 51 cases with tumours underwent examination by all method combinations except C, which was not used in 6 cases. Of these 51 cases, evaluation was possible in 27 by P, 18 by T, 44 by L and 37 by C (Fig. 3a). The 44 cases evaluable by combination L included all those in which an evaluation was possible with P, T and C.

Seven tumour cases in which a correct evaluation could not be made thus

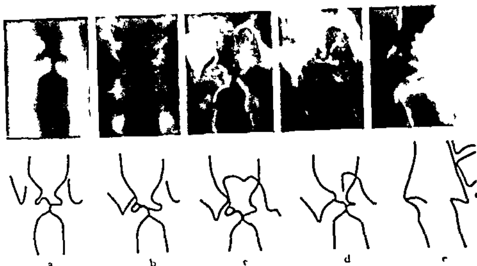


Fig 6 Tumour in the anterior part of the right true vocal cord extending into the right laryngeal ventricle to the lower surface of the right false vocal cord Tomography (a) ordinary radiography (b) and laryngography (c and e) during inspiratory phonation and laryngography during expiratory phonation (d) The infiltration of the tumour from the right true vocal cord into the laryngeal ventricle in the frontal projection is clearly evident only in ordinary radiography (b) and laryngography (c) during inspiratory phonation The surface of the tumour is irregular (c and e) Dotted area indicates region involved (a to e)

A potential of about 100 to 150 kV produced the best effects in the phantom examinations with contrast media The higher potential of 150 kV combined with 1 mm brass filtration, was used in laryngography to diminish the risk of obscuring a lesion in the layer of contrast medium For the same reason tube potentials of about 140 to 150 kV were employed in the lateral projection which also meant that the image of the often irregularly calcified laryngeal cartilages was reduced A high potential technique in laryngography was also favoured by POWERS et coll (1957) OGURA et coll (1960) LEHMANN & FLETCHER (1964) and HARRINGTON & CHRISTOFORIDIS (1970) The cinematograph technique with 30 frames/s and 80 to 90 kV and 50 to 60 kV in the frontal and lateral projections respectively corresponds with that recommended by LANDMAN (1970) and others

Tomography compared with ordinary radiography laryngography and cinematography It was mainly the laryngeal ventricle that was difficult to evaluate by tomography in lesions of the true or false vocal cords This region can best be assessed during inspiratory phonation (POWERS et coll 1964) in which the laryngeal ventricle becomes dilated (Fig 4 a b) thus means that compression of the ventricle can be differentiated from an infiltration This ma

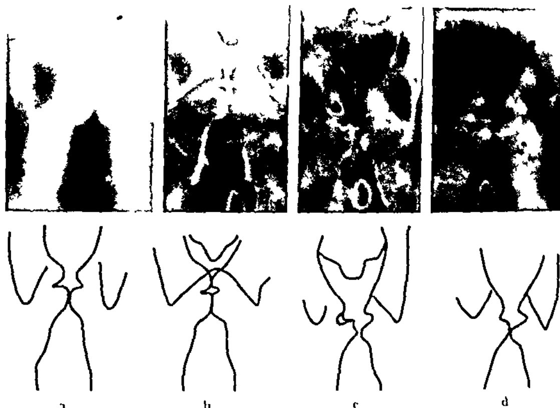


Fig. 5. Tumour of right true vocal cord extending to the right laryngeal ventricle. Tomography during inspiratory phonation (a). Laryngography during expiratory (b) and inspiratory (c) phonation and ordinary radiography during inspiratory phonation (d) in the frontal projection. The enlargement of the right vocal cord and the infiltration of the lesion into the right laryngeal ventricle occurs only when inspiratory phonation is performed adequately (c, d). Dotted area indicates region affected by the tumour (c, d).

Discussion

Technique. Linear tomography was selected as being the best to minimize the movement unsharpness that may so readily occur in examinations of the larynx (ARDRAN & EMRYS-ROBERTS 1965, LANDMAN 1970). A multisection cassette, which in tomography of the larynx in phantoms had proved to produce the same results as the single film system (HEMMINGSSON, to be published), was also employed so as to obtain tomograms during the same respiratory and phonation phases.

The tube potential of 150 kV with a 1 mm brass filter used in ordinary radiography, gave better frontal results than lower potentials (HEMMINGSSON, to be published); the phantom examinations at the same potential and filtration gave the best result at tomography. The multisection cassette utilized in the present investigation was adapted for lower potentials, however, and the tomographic examination therefore had to be performed without additional filtration



Fig. 8. Tumour of the left true vocal cord. Ordinary radiography (a) and laryngography (b) during inspiratory phonation in the lateral projection. The tumour is clearly defined only by laryngography (b). Dotted area indicates region affected (b). Dashed line defines contour not revealed by ordinary radiography (a).

Fig. 9. Tumour of the left true vocal cord extending to the anterior laryngeal wall. Ordinary radiography (a) and laryngography (b) during normal respiration in the lateral projection. The posterior surface of the tumour, the raised anterior part of the ventricle and the infiltration of the anterior laryngeal wall are clearly evident at laryngography (b); the laryngeal surfaces are irregular, the dotted area indicating the region affected. Dashed line defines contour not visible at ordinary radiography (a).

Ordinary radiography compared with laryngography and cinematography. The finding that the evaluation of the larynx was more reliable by positive contrast examination than by ordinary radiography agrees with the results of THORNBURY & LATOURETTE (1967) in 15 cases of malignancy. This is probably due mainly to the fact that in tumours and in oedema/fibrosis of the larynx there is too little *contrast* producing air so that the localization and extent of the lesion can more easily be determined when a layer of positive contrast medium surrounds and demarcates the lesion. This is the situation in

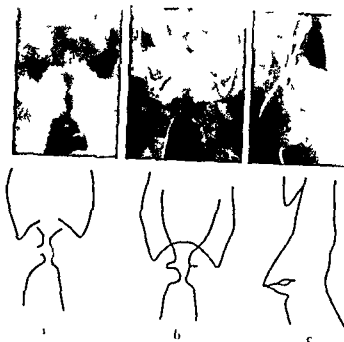


Fig 7 Synechia between the anterior parts of the vocal cords Ordinary radiography (a) and laryngography (b c) during inspiratory phonation The true and false vocal cords and the residual part of the laryngeal ventricle can be demarcated only in frontal laryngography (b), a spinous process is partly obscuring these structures on the right side Dashed line indicates contour not visible at ordinary radiography (a)

noeuvre is difficult to make during the relatively long exposure time that is required in tomography of laryngeal lesions, this explains to some extent why this method was the least reliable in tumours, the majority of which were situated to the glottic region (Table 2) The exposure time is short (not over 0 01 to 0 02 s) on the other hand in ordinary radiography, laryngography and cinematography, and with TV monitoring the exposure can be made when the patient is carrying out the manoeuvre adequately This is illustrated in Fig 5, where the extent of the lesion within the ventricle of the larynx could be determined only during inspiratory phonation with ordinary radiography and a contrast examination

Frontal tomography examination is not very reliable in lesions close to the anterior or posterior wall (LANDMAN 1970) In lesions of the posterior larynx this is probably due mainly to interfering blur from the cervical spine (HEMMINGSSON, to be published), while in anterior lesions it is perhaps on account of the lower radiographic contrast obtained in tomography (LITTLETON & WINTER 1965 WOLF et coll 1971) that this gives poorer results in these cases than other methods This is evident in Fig 6, in which a tumour in the anterior part of the right vocal cord invading the ventricle of the larynx towards the lower surface of the false vocal cord could be clearly demarcated by ordinary radiography and laryngography but not by tomography The infiltration of the laryngeal ventricle again in this case can be clearly assessed only when the ventricle is dilated, i e during inspiratory phonation (Fig 6 c, d)

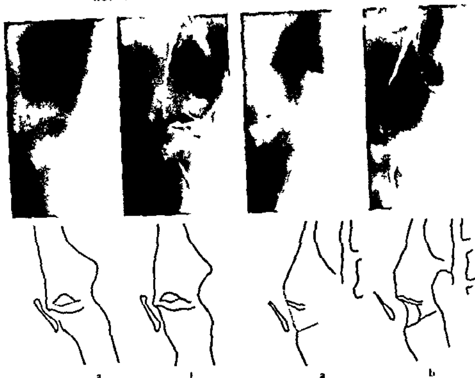


Fig. 8 Tumour of the left true vocal cord. Ordinary radiography (a) and laryngography (b) during inspiratory phonation in the lateral projection. The tumour is clearly defined only by laryngography (b). Dotted area indicates region affected (b). Dashed line defines contour not revealed by ordinary radiography (a).

Fig. 9 Tumour of the left true vocal cord extending to the anterior laryngeal wall. Ordinary radiography (a) and laryngography (b) during normal respiration in the lateral projection. The posterior surface of the tumour, the raised anterior part of the ventricle and the infiltration of the anterior laryngeal wall are clearly evident at laryngography (b); the laryngeal surfaces are irregular, the dotted area indicating the region affected. Dashed lines contour not visible at ordinary radiography (a).

Ordinary radiography compared with laryngography and cinematography
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Fig. 7, where a synechia between the anterior part of the vocal cords had reduced the length of the ventricle of the larynx in the sagittal direction. The true and false vocal cords and the residual part of the laryngeal ventricle can therefore be demarcated only when their surfaces are coated with positive contrast medium. The same situation in the lateral projection is illustrated in Fig. 8, where the tumour, with a central excavation, may be distinguished clearly only when coated with contrast medium. A further example of this is given in Fig. 9, in which a tumour involving the anterior wall of the larynx at the level of the vocal cords can be defined posteriorly only with a positive contrast medium.

The contour of the mucosa is irregular, signifying its destruction or infiltration in Fig. 9. This is one of the most important signs of malignancy of the larynx (LEHMANN & FLETCHER 1964, BRINDLE & STELL 1968, KANAMITSU 1968) and is evident only when the mucosa is coated with contrast medium. An irregular mucosal contour occurred in 75 per cent of malignant tumours. The roentgenologic examination must be made before biopsy is performed if this finding is to be correctly evaluated.

Subtraction, which according to CHIESA & CARESANO (1967) is an alternative to other methods of examination, failed to improve the possibilities of evaluation except in one case. This is due to the fact that the same position of the cervical spine could not be obtained during quiet respiration and phonation.

Laryngography compared with cinematography. Laryngography in some adult subjects gave better possibilities of correct assessment than cinematography (Table 3, Fig. 3). The coating of contrast medium in these cases was sparse, and the lower contour sharpness and resolution that are obtained by cinematography probably explain why the small structures in the larynx could not be defined. A correct evaluation could be made with laryngography (Fig. 3, for tumours and oedema/fibrosis) in all adults in whom it was possible with cinematography. These results are in agreement with observations reported by LANDMAN (1970) and others. Cinematography is, however, of value in adults for evaluation and especially documentation of the motility of the laryngeal structures. Cinematography constituted a complement to laryngography in 2 small infants for evaluation of the morphology and motility of the larynx. The reason for this was that the infants were unable to cooperate actively in the examination.

Conclusion

This investigation has indicated that the laryngography is the most reliable method of radiographic examination of the larynx and should be used whenever possible. Cinematography, which did not produce better evaluation in adults,

is of value in examining small infants who are unable to cooperate actively. Furthermore this method enables the motility of the structures to be easily assessed and documented.

Ordinary radiography, which in no case gave a better result than laryngography, should be used on the other hand where a positive contrast examination is contraindicated, e.g. in hypersensitivity to the anaesthetic or contrast medium. With a high potential technique better results can be obtained with ordinary radiography than with tomography. Subtraction between ordinary films during respiration and phonation improves the diagnostic possibilities only in a few isolated cases.

Tomography may sometimes produce better results than ordinary radiography when only small amounts of contrast producing air are present in the larynx, for example due to oedema/fibrosis, and may also be a complement to laryngography if the coating with positive contrast medium is poor. Small exposure angles, which mean a short exposure time, are preferable so that the least possible unsharpness due to movement is obtained.

SUMMARY

Different methods of roentgenologic examination of the larynx, namely tomography, ordinary radiography with a high potential technique, laryngography and cinematography were compared. The results in 119 examinations indicated that laryngography is the most reliable method in adults, while cinematography was the method of choice in small children. Ordinary radiography with a high potential technique should be used if a positive contrast examination must be excluded, while tomography is an advantage in only a few cases.

ZUSAMMENFASSUNG

Verschiedene Methoden der röntgenologischen Untersuchung des Larynx, nämlich Tomographie, gewöhnliche Radiographie mit hoher Kilovolttechnik, Laryngographie und Kinematographie werden miteinander verglichen. Die Ergebnisse von 119 Untersuchungen deuten darauf hin, dass die Laryngographie bei Erwachsenen die zuverlässigste Methode ist, während bei kleinen Kindern die Kinematographie die Methode der Wahl ist. Die gewöhnliche Radiographie mit hoher Kilovolttechnik sollte verwendet werden, falls eine positive Kontrastuntersuchung ausgeschlossen werden muss, während die Tomographie nur in wenigen Fällen von Vorteil ist.

RÉSUMÉ

L'auteur a comparé différentes méthodes d'examen radiologique du larynx: la tomographie, la radiographie ordinaire en technique de haute tension, la laryngographie et la cinématographie. Les résultats sur 119 examens ont montré que la laryngographie est la meilleure méthode chez les adultes, alors que la cinématographie est la méthode de choix chez les petits enfants. La radiographie ordinaire avec la technique de haute tension doit être utilisée si on est obligé de renoncer à un examen avec contraste positif. La tomographie n'est avantageuse que dans un petit nombre de cas.

REFERENCES

ARDRAN G M and EMRYS ROBERTS E Tomography of the larynx Clin Radiol 16 (1965) 369

BRAUER W Die Methodik der Larynx Kontrast Schichtuntersuchung *Fortschr Rontgenstr* 82 (1955), 521

BRINDLE M J Radiology of the larynx M D Thesis University of Liverpool 1966

— and STELL P M Radiological assessment of laryngeal carcinoma Clin Radiol 19 (1968) 257

CHIESA A e CARESANO A La sottrazione d immagini nello studio della laringe con radiazioni filtrate (In Italian) Quad Radiol 32 (1967) 273

FABRIKANT J I RICHARDS G J, FUCKER G F and DICKSON R J Contrast laryngography in the evaluation of laryngeal neoplasms Amer J Roentgenol *87 (1962) 822*

FARINAS P L Mucosography of the respiratory tract Radiology 39 (1942) 84

HARRINGTON J W and CHRISTOFORIDIS A J Radiological examination of the larynx Laryngoscope *80 (1970) 1773*

HEMMINGSSON A Roentgenologic methods in examination of the larynx Comparative phantom investigations in frontal projection To be published in Acta radiol Diagnosis

HOLTZ S, POWERS W McGAVRAN M and OGURA J Contrast examination of the larynx and pharynx Amer J Roentgenol 89 (1963) 10

KANAMITSU M A study on the laryngography as a diagnostic method of the hypopharyngeal cancer and laryngeal cancer Nippon Acta radiol 28 (1968) 511

KIRCHNER J A SCATLIFF J H and SCHEDD D P Cinefluorography in the pre and post operative management of laryngeal cancer Ann *Otol (St Louis) 69 (1960) 768*

KOVÁCS A Asymmetric roentgenography of the vocal cords Acta radiol 53 (1960) 426

— Roentgen physiology of the larynx Acta radiol 56 (1961) 433

— Roentgenologic examination of the arytenoid cartilage and ventricle of Morgagni in the functioning larynx Acta radiol Diagnosis 2 (1964) 379

LANDMAN G H M Laryngography and cinelaryngography Excerpta Medica Foundation Amsterdam 1970

LEBORGNE F E Nueva técnica radiologica per cortes o secciónes (In Spanish) An Ateneo *Clin quir (Montevideo) 13 (1936) Cited by Landman (1970)*

LEHMANN Q H and FLETCHER G H Contribution of the laryngogram to the management of malignant laryngeal tumors Radiology 83 (1964) 486

LINDGREN E Über die Röntgenuntersuchung des Larynx Fortschr Rontgenstr *59 (1939)* 273

LITTLETON J T and WINTER F S Linear laminagraphy A simple geometric interpretation of its clinical limitations Amer J Roentgenol 95 (1965) 891

MAGUIRE G H The larynx Simplified radiological examination using heavy filtration and high voltage Radiology 87 (1966) 102

— BEIQUE R A and ROTENBERG A D Selective filtration The practical approach to high kilovoltage radiography Radiology 85 (1965) 343

MÅRTENSSON B Transconioscopy in cancer of the larynx *With special reference* to the detection of subglottic extension Acta oto laryng (1967) Suppl No 224 p 476

Mc DONNEL G M BERMAN H I and LODMELL E A Supervoltage roentgenography Amer J Roentgenol 39 (1958) 306

MEDINA J SEAMAN W CARBAJAL P and BAKER D Value of laryngography in vocal cord tumors *Radiology 77 (1961) 531*

OGURA J and BILLER H Conservation surgery in cancer of the head and neck Ot laryng Clin N Amer (1969) p 641
— POWERS W M HOLTZ S et coll Laryngograms their value in the diagnosis and treatment of laryngeal lesions Laryngoscope (St Louis) 70 (1960) 780
PEREZ C A OGURA H J HOLTZ S et coll Laryngography in the selection of patients for conservation surgery in cancer of the supraglottic larynx and pharynx Amer J Roentgenol 103 (1968) 746
POWERS W E McGEE H H and SEAMAN W B Contrast examination of the larynx and pharynx Radiology 68 (1957) 169
— HOLTZ S and OGURA J Contrast examination of the larynx and pharynx Inspiratory phonation Amer J Roentgenol 92 (1964) 40
— — — et coll Contrast examination of larynx and pharynx Accuracy and value in diagnosis Amer J Roentgenol 86 (1961) 651
RÉTHI A Die Rontgenuntersuchung des Kehlkopfes und der Luftrohre Dtsch med Wschr 38 (1912) 1937
SCHOEN D Hartstrahltechnik und Feinfokusrohre in der Diagnostik des Kehlkopfes Fortschr Rontgenstr 78 (1953) 170
SCHUERMANS J et BROMBART M Radiocinématographie des cordes vocales Acta oto-rhino-laryng belg 12 (1958) 427
TASKINEN P J Radiotherapy and TNM classification of cancer of the larynx Acta radiol (1969) Suppl No 287
THORNBURY J R and LATOURETTE H B A comparison study of laryngography techniques 150 kvp plain roentgenography vs positive contrast roentgenography Amer J Roentgenol 99 (1967) 555
UICC TNM classification of malignant tumours International Union against Cancer Geneva 1968 Cited by Taskinen (1969)
VIGNAUD-PASQUIER J DANIC J et SUDAKA J La méthode de soustraction Application à la radiographie en O R L Rev Laryng (Bordeaux) (1963) Suppl No 663
WALDAPFEL R Methodik der Rontgenuntersuchung des Kehlkopfes Georg Thieme Verlag Leipzig 1938
WOLF G CANIGIANI C und NEUMANN H Die Korperschichtuntersuchung und die Kontrastdarstellung des Larynx Ein Vergleich zwischen zwei Untersuchungsarten Fortschr Rontgenstr 114 (1971) 536
YOUNG B R Recent advances on roentgen examination of the neck Body section roentgenography (planigraphy) of the larynx Amer J Roentgenol 44 (1940) 519

REFERENCES

ARDRAN G. M. and EMRYS ROBERTS E.: Tomography of the larynx. Clin. Radiol. 16 (1965), 369.

BRAUER W.: Die Methodik der Larynx-Kontrast-Schichtuntersuchung. Fortschr. Röntgenstr. 82 (1955), 521.

BRINDLE M. J.: Radiology of the larynx. M. D. Thesis. University of Liverpool 1966.

— and STELL P. M.: Radiological assessment of laryngeal carcinoma. Clin. Radiol. 19 (1968), 257.

CHIESA A. e CARESANO A.: La sottrazione d'immagini nello studio della laringe con radiazioni filtrate. (In Italian.) Quad. Radiol. 32 (1967), 273.

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FARINAS P. L.: Mucosography of the respiratory tract. Radiology 39 (1942), 84.

HARRINGTON J. W. and CHRISTOFORIDIS A. J.: Radiological examination of the larynx. Laryngoscope 80 (1970), 1773.

HEMMINGSSON A.: Roentgenologic methods in examination of the larynx. Comparative phantom investigations in frontal projection. To be published in Acta radiol. Diagnosis.

HOLTZ S., POWERS W., MCGAVRAN M. and OGURA J.: Contrast examination of the larynx and pharynx. Amer. J. Roentgenol. 89 (1963), 10.

KANAMITSU M.: A study on the laryngography as a diagnostic method of the hypopharyngeal cancer and laryngeal cancer. Nippon Acta radiol. 28 (1968), 511.

KERCHNER J. A., SCATLIFF J. H. and SCHEDD D. P.: Cinefluorography in the pre- and postoperative management of laryngeal cancer. Ann. Otol. (St. Louis) 69 (1960), 769.

KOVÁCS A.: Asymmetric roentgenography of the vocal cords. Acta radiol. 53 (1960), 426.

— Roentgen physiology of the larynx. Acta radiol. 56 (1961), 433.

— Roentgenologic examination of the arytenoid cartilage and ventricle of Morgagni in the functioning larynx. Acta radiol. Diagnosis 2 (1964), 379.

LANDMAN G. H. M.: Laryngography and cinelaryngography. Excerpta Medica Foundation, Amsterdam 1970.

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LEHMANN Q. H. and FLETCHER G. H.: Contribution of the laryngogram to the management of malignant laryngeal tumors. Radiology 83 (1964), 486.

LINDGREN E.: Über die Röntgenuntersuchung des Larynx. Fortschr. Röntgenstr. 59 (1939), 273.

LITTLETON J. T. and WINTER F. S.: Linear laminagraphy. A simple geometric interpretation of its clinical limitations. Amer. J. Roentgenol. 95 (1965), 891.

MAGUIRE G. H.: The larynx. Simplified radiological examination using heavy filtration and high voltage. Radiology 87 (1966), 102.

— BRIQUE R. A. and ROTHENBERG A. D.: Selective filtration. The practical approach to high kilovoltage radiography. Radiology 85 (1965), 343.

MÅRTENSSON B.: Transconioscopy in cancer of the larynx. With special reference to the detection of subglottic extension. Acta oto-laryng. (1967) Suppl. No. 224, p. 476.

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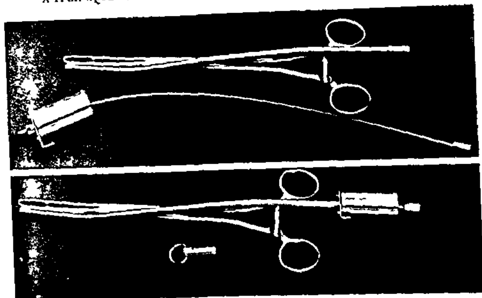


Fig 1 The tenaculum with the attached steel tube The safety container with its ⁵⁷Co source is fixed to the tube in the lower part of the figure when it is removed the plug of steel and lead is inserted to shield the radiation All parts are of stainless steel

active source consists of a steel container 8 mm in length and with an outer diameter of 4 5 mm containing ^{57}Co prepared by evaporating ^{57}Co chloride in the source container the latter is secured to a flexible steel cable (Fig 1)

The tenaculum is fastened close to the internal cervical os of the patient in the gynecologic department (Fig 2) The radioactive source will be located between the internal and external cervical os An a p film obtained after injection of 1 mCi ^{113}In^{m} chloride will include the round circle from the reticule illumination After the first view of the placenta the pulse height analyser is set to accept the 120 keV gamma rays from the ^{57}Co The security holder of lead and steel is fastened to the steel tube and the radioactive source is introduced until contact with the steel plug is obtained A marker on the flexible leader must be in contact with the security holder to ensure that the source is in the right position About 2 000 counts are accumulated in a further film which with a source strength of about 1 mCi for the anterior projection takes 3 to 5 s and for lateral projection 7 to 10 s The intensity setting on the oscilloscope is the same as for the ^{113}In^{m} views The indication procedure being completed the radioactive source is withdrawn and a lateral projection of the placenta is taken and the same procedure of indicating the position of the uterine cervix performed Finally the Co

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A TECHNIQUE FOR THE LOCALIZATION OF THE INTERNAL CERVICAL OS IN PLACENTA SCINTIGRAPHY

by

P. E. ASARD, H. GUSTAVSSON, S. NORDLANDER and B. WESTIN

One of the main problems in placenta praevia diagnostics with radionuclides is to localize the placenta in relation to the internal cervical os. The most obvious solution is to introduce a radioactive source into the uterine cervix and thus obtain a marking in the scintigram. This procedure must be such, however, that the radiation dose to the foetus and patient is negligible. The radioactive source must also be so applied that its position is correct. A special technique that fulfills these requirements and is easy to perform in routine work will be described.

Material and Methods. A stainless steel tube of 5 mm inner diameter is soldered to a special tenaculum (Fig. 1). A plug of steel and lead, which will diminish any radiation in the direction of the foetus is inserted in the end of the tube; the wall thickness in front of the plug has been reduced to 0.15 mm in order to decrease the gamma ray absorption in the wall. The special tube is always kept ready sterilized at the delivery department of the hospital with the radioactive source in its safety container in the isotope laboratory. The radio-

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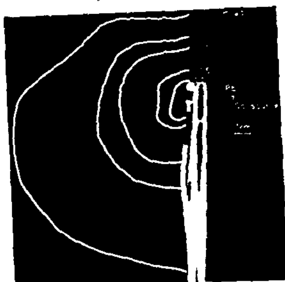


Fig. 3. The isodose distribution around the radioactive source obtained with LiF dosimetry. The source contains about 1.5 mCi ^{57}Co

Discussion

ROSENTHALL (1969) described a technique for the localization of the uterine cervix by means of intravaginal markers. This differs from the present method in that this author used a ^{19}Au or ^{131}I source fitted on a disposable cervicopudendal injection set. The insertion of the radioactive source was performed blindly or by means of a speculum for each view taken. The present technique seems to be an improvement as it is based on an afterloading technique which means that the special tube is inserted before the scanning procedure. It is important that the insertion of the radioactive source can be performed easily and several times during the investigation and that the patient remains in the same position as when the scintigraphic views are taken.

The marking technique has been used as a routine in placenta scanning with a Pho-Gamma III gamma camera for about six months and in 35 patients to date. The attachment of the tenaculum has formed part of an ordinary vaginal speculum investigation. It causes no discomfort and since no palpation is done there is no risk of complications.

The marking of the internal cervical os is important (Fig. 4 a, b). The anterior scintigram in the figure suggests a total placenta praevia, the lateral scintigram with the marking of the internal os indicates however that the placenta praevia is a marginal one. The marking technique presented in this paper may of course also be used with a rectilinear scanner. The source strength must then, however



Fig. 2. a) The position of the applicator in a.p. view. b) The position of the applicator in lateral view.

markings on the polaroid images are projected by means of transparent papers onto the scintigrams of the placenta. The reticule illumination circles insure the superposition of the two images being correct.

Results

The radiation dose to the foetus and patient may be estimated (Fig. 3). The dose distribution around the ^{57}Co source in the steel tube was measured by means of TLD dosimetry, the dosimeters were of teflon and 5 mm in diameter and 1 mm thick. These measurements indicate that an exposure time of 10 s gives a maximum dose to the foetus of less than 0.5 mrad, that to the patient at the contact surface between the wall of cervix and the steel tube has been estimated by extrapolation to be about 10 mrad for 10 seconds exposure. These figures hold for a ^{57}Co source of about 1.5 mCi but will be approximately correct for any other source strength, if 2 000 counts are necessary to produce a suitable exposure of the polaroid film.

Practically the only radiation of the film originates from the ^{57}Co source because this is well localized (Fig. 4 c). If 1 mCi $^{113}In^m$ is used for the placenta scanning, 50 to 70 per cent of the preset 2 000 counts in the marking procedure come from the Compton scattered $^{113}In^m$ photons. As these are distributed over a larger area they will not be reproduced in the film.

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MODIFIED THEORY OF THE DEVELOPMENT OF TOMOGRAPHIC BLURRING

by

SVEN REICHMANN

The depth of zone within the object that can be examined in one single tomogram should be appreciated. KIEFFER (1939) and POSCHL (1940) in classical theoretic investigations considered the factors that determined the thickness of the section. The research was based upon how single points situated outside the tomographic plane move in the film during the exposure. The dependence on the tomographic angle, the distance from the tomographic plane, the distances between the focus and object as well as between object and film were calculated. EDHOLM (1960) later stressed the importance of the thickness of the screen film combination and size of tube focus.

One obstacle exists in these presentations. The roentgenogram is not generated from single object points. This is not easy to understand but the application of the information theory to radiography (SCHOBER 1962, ROHLER 1962, MORGAN 1966) has confirmed this premise. One basic concept in this theory is the signal/noise ratio. The roentgenogram is always formed by roentgen photons absorbed within the depicting medium, i.e. in the fluoroscopic screen, the film, or the screen film system. Each photon *gives rise to an* image point of reduced silver if registration be made in film. The variation in blackening of the film is produced

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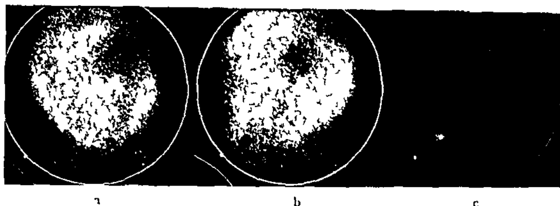


Fig. 4. a) Anterior scintigram of a placenta obtained with a diverging collimator after injection of 1 mCi ^{113}In^{m}. A total of 100 000 counts has been accumulated. The marking in the film indicates the position of the uterine cervix. b) Lateral scintigram. c) The ^{57}Co marking point is indicated in the lateral scintigram: 2 000 counts in 10 s.

probably be diminished for the same dose levels as the time for the localization and selective scanning of the marker will be longer than that with the gamma camera.

SUMMARY

A method of localizing the internal cervical os of the uterus in placenta scintigraphy based on an afterloading technique is described. Details of the construction of a special applicator utilizing a ^{57}Co source are described.

ZUSAMMENFASSUNG

Es wird eine Methode, den inneren Cervikalmund des Uterus bei der Plazentascintigraphie zu lokalisieren, die auf einer Nachladetechnik beruht, beschrieben. Einzelheiten der Konstruktion eines speziellen Applikators unter Anwendung einer Co-Quelle werden beschrieben.

RÉSUMÉ

Description d'une méthode de localisation de l'orifice interne du col de l'utérus sur la scintigraphie placentaire basée sur une technique de charge après la mise en place. Description de détails de la construction d'un applicateur spécial utilisant une source de ^{57}Co.

REFERENCE

ROSENTHALL, L. Intravaginal markers for accurate radionuclide localization of the placenta. Amer. J. Roentgenol. 106 (1969) 787.

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by the absorption within the object of part of the roentgen photons. The fluctuations in roentgen photon density behind the different parts of the object thus constitute the signal since they give rise to the contours in the roentgenogram.

The noise of a radiographic system may be produced in several ways. One noise is the quantum mottle, caused by the mere fact that a roentgenogram is built up of a finite number of roentgen photons. Even if no absorbing object lies in the roentgen beam, the photons will not strike the film in a perfectly homogeneous manner but will fluctuate from area to area. These fluctuations are caused by the statistical chance of each unit area being struck by photons. If a sensitive screen film system be used, the image will be built up of a few photons, the statistical chance of photon fluctuations between different areas will be high. Thus high sensitivity makes for a high quantum mottle. Signals that are below the level of the quantum mottle will not appear in the roentgenogram.

The noise may also develop differently. Secondary radiation may thus be looked upon as a variety of noise since it disturbs the possibility of detecting the signals when it produces a basal fog in the roentgenogram. A third kind of noise is made up of signals arising from overprojecting structures of little diagnostic interest. Thus it is well known that the contours from the middle ear and internal ear in conventional roentgenography of the skull will be hidden by other contours to such a degree as to become more or less imperceptible, tomography is therefore often employed.

A contour is rendered visible largely by the ratio between the signal and the *noise intensities, when this ratio is favourable the signal intensity* is high and the noise intensity low.

Every roentgenographic system has its own noise level and in clinical roentgenography this is usually high. Signals that give rise to visible contours can therefore never arise from such small objects as points outside the tomographic plane (Poseur). Perceivable changes in blackening density are however caused only by object parts with a certain depth in the direction of the roentgen beam. Such structures always have surfaces against the surroundings where tissues, such as bone and soft tissue, of different absorption properties for roentgen photons meet. The contours in the roentgenogram are formed when such surfaces are struck tangentially by the roentgen rays, these surfaces, will be called absorption boundaries. The noise of the roentgenographic systems will therefore make it necessary to investigate the blurring not of single points but of absorption boundaries, since only the latter can give rise to signals sufficiently intense as to exceed *the noise level*.

A theoretic analysis will be presented of how the blurring of contours from absorption boundaries outside the tomographic plane arises. A practical test will then be described.

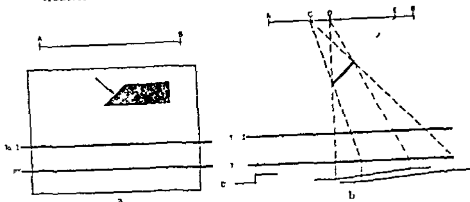


Fig 1 The development of contour dispersion and movement A part of specific absorption lies within the object (a) One of the absorption boundaries (arrow) is examined in (b) for focus location C D and E Two tomographic planes To P I and To P II are marked The contour dispersion is the spreading out of the contour at its greatest when the focus is at C and zero when it is at E The corresponding slope of the density relief (D R) for the lower tomographic plane is indicated at the bottom of the figure When the focus moves from C to E the contour more or less dispersed crosses from right to left over the tomographic planes

Theoretic analysis

Contours arising from absorption boundaries outside the tomographic plane are blurred by two separate mechanisms contour dispersion and contour motion (Fig 1) Fig 1 a indicates how the absorption boundary may arise only the absorption boundary appears in Fig 1 b The focus of the roentgen tube moves during the exposure from A to B in a linear movement perpendicular to the plane absorption boundary Two tomographic planes are marked in the figure at different levels These may be present at the same time if two films be used in simultaneous tomography but the planes may equally well represent the tomographic plane at two different single tomographies

The determination of the projection of objects lying outside the tomographic plane may be accomplished from the projection formed on the tomographic plane corresponding to the film Each point of the tomographic plane is represented in the film the absorption boundary (Fig 1) may thus be investigated when projected onto the two tomographic planes Comparison of the planes indicates how the distance to the tomographic plane affects the blurring

Fig 1 b presents the manner in which the actual absorption boundary is projected onto the two tomographic planes at three different moments during the exposure Below the lower tomographic plane the principal density relief is indicated that would have been present in the corresponding film if each one of the focus positions had been stationary and tomography had not been performed A sharp contour would have occurred with the focus at position E It may therefore be concluded that during part of the tomographic exposure a sharp represen

tation of the absorption boundary is possible when it be struck tangentially by the roentgen rays.

The blackening reliefs indicated from focus positions C and D have such a slope as to preclude the perception of a contour even in conventional roentgenography (motionless roentgen tube). The greater the angle between the central ray and the absorption boundary, the greater will be the slope of the corresponding blackening relief. Finally, it may now be stated that the relief changes continuously during the tomographic exposure, the slope becoming most upright when the absorption boundary is struck by tangential roentgen rays. This change of slope in the blackening relief must be part of the tomographic blurring and will be termed 'contour dispersion'.

The main factor determining contour dispersion is the incidental angle of the roentgen beam in relation to the absorption boundary. The distance between the latter and the tomographic plane is of certain importance due to the divergence of the roentgen beam.

The projection of the absorption boundary will move over the tomographic plane during the exposure (Fig. 1 b). This process will be termed 'contour motion'. This type of blurring is mostly dependent on the distance to the tomographic plane.

Contour dispersion and contour motion interlace in forming tomographic blurring. The interesting point is that during part of the exposure the contour dispersion is so low, i.e. during the moment when the absorption boundary is struck by tangential roentgen rays, that a sharp contour would have been formed *if the contour motion had been absent.* Certain unsharpness may be presumed to be tolerable in the contour that may form from the absorption boundary, so that the part of the tomographic exposure at which a sharp contour may arise is not the infinitely short moment when the absorption boundary is struck tangentially. On the other hand it also includes a time period before and after this moment. This part of the exposure, when an acceptably sharp contour would have arisen in conventional roentgenography, will be called the 'contour period' for the absorption boundary in question.

Blurring during the contour period is due to contour movement. Inversely, contour movement is less important during the greater part of the exposure since the contour dispersion will then be such that a contour cannot be formed; with no contour no blurring will be necessary.

Reference to the information theory, as mentioned in the introduction, will now have to be made. The absorption boundary outside the tomographic plane may give rise to a contour during the contour period. An examination of the site in the film onto which this contour is projected will reveal that the film will receive a signal during the period. Roentgen photons during the remainder

of the exposure will fall onto the same part of the film without supplying any information about the absorption boundary in question these will thus constitute a sort of radiographic noise The signal/noise ratio for the contour that may be formed from the absorption boundary outside the tomographic plane may be made increasingly unfavourable if the contour period constitutes a smaller and smaller part of the total exposure It is more a matter of dose than time The smaller the roentgen dose at the contour site in the film during the contour period in relation to the total dose that reaches the same site the more unfavourable the signal/noise ratio for the contour in question will be

The blurring of the actual contour from the absorption boundary outside the tomographic plane is dependent on two mechanisms (1) The contour moves over the film during the contour period (2) the contour is formed only by part of the total roentgen dose the rest of the dose for the same film area constituting obscuring noise The factors influencing the section thickness will now be considered

The distance between the absorption boundary and the tomographic plane affects both the contour movement and the contour dispersion both factors increasing directly with distance The increase in contour dispersion will in fact lead to a decrease in the contour period this in turn leading to an impaired signal/noise ratio At the same time the contour moves faster during the contour period the resultant effect being a decrease in the visibility of the contour when the distance to the tomographic plane is increased

An increase in the tomographic angle affects neither the absolute length of the contour period nor contour movement if the angular velocity of the tomographic motion be kept constant. The factor changed through the increase is now the signal/noise ratio due to an increase in the noise This occurs because more photons will reach the contour area in the film without having passed the absorption boundary tangentially The same impairment in signal/noise ratio affects contours from absorption boundaries in the tomographic plane This is reflected in a decrease of contrast in these contours when the tomographic angle is increased Since the contours produced by absorption boundaries outside the tomographic plane, for the reasons mentioned above will generally have a lower visibility than those from identical absorption boundaries in the tomographic plane the former contours are the first to be extinguished when the tomographic angle is increased This increase thus leads to the well known decrease in section thickness

Apart from the geometric blurring the signal/noise ratio is thus of essential importance in the formation of the tomographic effect Since this ratio can be altered in many ways apart from those mentioned some further factors affecting section thickness have to be considered

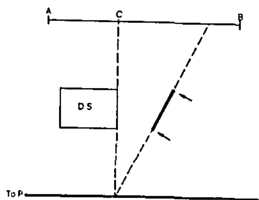


Fig. 2

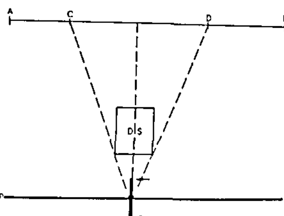


Fig. 3

Fig. 2. Tomography of an absorption boundary (arrows) outside the tomographic plane when a highly absorbing structure (D S — dense structure) is present beside the absorption boundary. The contour area for the absorption boundary on the tomographic plane To P is reached only by attenuated noise radiation that has passed the dense structure when the focus moves between A and C.

Fig. 3. Tomography of an absorption boundary (arrows) when the depicting rays are attenuated by the passage through a dense structure D S. The corresponding noise radiation is attenuated only when the focus moves from C to D.

The signal intensity from absorption boundaries outside the tomographic plane may be increased by either of the following mechanisms: (1) Any factor leading to an increase in contrast of the contour, apart from the photographic factors that determine the film contrast, (2) angular variations in the intensity of the roentgen beam. An increase in contrast may be achieved by a lowering of the *kilovoltage to the roentgen tube. This effect is interesting since tomography with* large angles and the lowest kilovoltage possible is usually recommended. The lowering would thus be expected to counteract the decrease in section thickness obtained by the increase in tomographic angle.

The nature of the absorption boundary also affects signal intensity. A plane absorption boundary is used in Fig. 1a. The signal intensity here may be increased in two ways: (1) by an increase in the absorption difference across the absorption boundary, (2) by an increase in the depth of the absorption boundary in the direction of the tangential roentgen beam. Most absorption boundaries are not plane but may be regarded as being built up of cylindric or spherical surfaces. These, in turn, may be regarded as consisting of a large number of small plane surfaces, so that the principles described for such *will be* applicable to curved surfaces as well. The depth of a curved surface in the direc

tion of the roentgen beam at a given moment will depend on the length of the radius of the curvature the depth increasing with the radius

Angular variations in the intensity of the roentgen beam were considered in another investigation of tomography (REICHMANN 1972) They were found to give rise to contours that were called spurious contours, a term commented on below The variations may arise in several ways (1) By such a construction of the tomographic movement path that the roentgen focus will be in one sector of the area limited by the tomographic angle for a longer time than it is in other sectors provided the dose rate of the focus be constant, (2) by parallelism between the absorption boundary and part of the tomographic movement path (3) by variations in the anode current of the roentgen tube Since these factors — especially the first two — were investigated earlier (REICHMANN) it will be sufficient to state that points (1) and (2) in fact express the same thing, (2) being only a special case of (1)

The signal/noise ratio may however be altered in ways other than those primarily concerning the intensity of the signal Such alterations will arise if the signal be kept constant and the noise changed The noise made up of secondary radiation is important It is added to all other kinds of noise present so that a reduction in secondary radiation for example by insertion of a Bucky grid will reduce the total noise level and increase the section thickness The quantum mottle as described in the introduction is another important type of noise As this is reduced when the sensitivity of the recording medium the *film or screen* film system is reduced such a reduction should, at least at times give rise to an increase in section thickness A mechanism for the change in noise level is depicted in Fig 2 An absorption boundary and a highly absorbent structure lie *outside* the tomographic plane During the contour period for the *absorption* boundary in question the roentgen rays are not affected by the dense structure *but during* a large part of the remainder of the exposure the radiation that produces the noise for the contour analysed will be attenuated *The* absorption boundary will be more clearly depicted than it would *have* been if the dense structure had not been there

An absorption boundary screened off during the contour period *by a dense structure* outside the tomographic plane appears in Fig 3 The signal is attenuated more than the noise and consequently *the depiction* will be impaired

Practical test

The intention was to investigate the blurring of simple absorption boundaries situated outside the *tomographic plane* The effect of an increase in the tomographic angle was compared *with that produced* by means of a direct change in the signal/noise ratio The latter *change was* induced in two separate ways

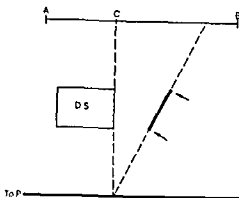


Fig 2

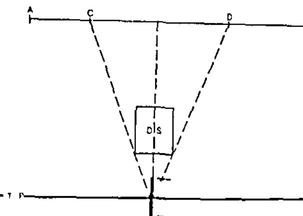


Fig 3

Fig 2 Tomography of an absorption boundary (arrows) outside the tomographic plane when a *highly absorbing structure (D S — dense structure) is present beside the absorption* boundary The contour area for the absorption boundary on the tomographic plane To P is reached only by attenuated noise radiation that has passed the dense structure when the focus *moves between A and C*

Fig 3 Tomography of an absorption boundary (arrows) when the depicting rays are attenuated *by the passage through a dense structure D S The corresponding noise radiation is attenuated* only when the focus moves from C to D

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and 15 but the exposure was repeated three times the roentgen dose each time being a third of that in the first tomographic exposure The object with the scores was present in the roentgen beam only once and was taken away during the other two parts of the exposure A change in the signal/noise ratio was thus induced The fourth tomogram was made in the same way as the first one but with the tube potential increased from 40 to 100 kV

Some of the results of the procedure appear in Fig 4 Both sets of cores were clearly visible in the first tomogram at 40 kV and 15 (Fig 4 a) When the tomographic angle was increased the visibility was lowered (Fig 4 b) the same effect being produced in the third and fourth tomograms (Fig 4 c) It may thus be stated that a change in the tomographic blurring of contours from absorption boundaries outside the tomographic plane may be produced not only by a change in the tomographic angle but also by procedures directly altering the signal/noise ratio

Discussion

The hypothesis presented has only partly been confirmed by practical tests It implies however application to tomographic geometry only of a general principle used for conventional roentgenography for about a decade i e the signal/noise ratio afforded by the theory of information There is no reason why it should not be as valid in tomography as in ordinary radiography The present hypothesis as to the development of tomographic blurring confirms certain factors that have been known for a long time one of which is the generation of spurious contours

The term section thickness seems to be somewhat dubious and cannot be used as a general one since many factors will alter the representation of different parts of the object The expression could at the most be used for one absorption boundary at a time but then it certainly loses its meaning It is probably more appropriate to consider whether the structures to be examined in a given case are sufficiently well depicted and whether the others are adequately removed

A distinction was made between true and spurious contours in an earlier investigation (REICHMANN) It was postulated that true contours are formed from absorption boundaries in the tomographic plane and in a zone in its vicinity called the tomographic zone Spurious contours were considered to be formed only from absorption boundaries outside the tomographic zone The present hypothesis as to tomographic blurring further develops this line of thought so that these terms may be more strictly defined A spurious contour was originally defined as a contour arising from an absorption boundary situated so far away from the tomographic plane that it would have been removed if the

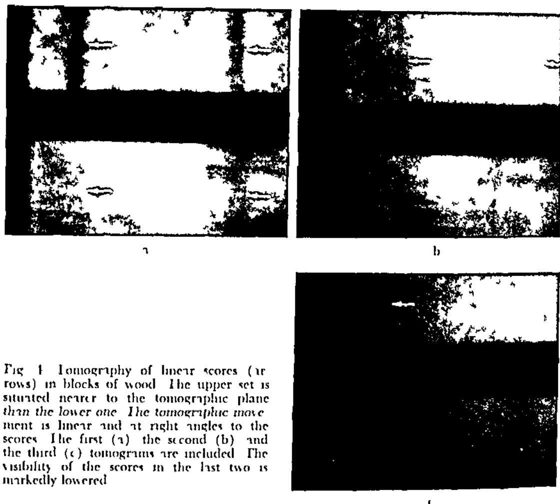


Fig. 4. Tomography of linear scores (arrows) in blocks of wood. The upper set is situated nearer to the tomographic plane than the lower one. The tomographic movement is linear and at right angles to the scores. The first (a), the second (b) and the third (c) tomograms are included. The visibility of the scores in the last two is markedly lowered.

The test object consisted of two blocks of wood. Parallel 1 mm scores had been made in the upper surface of each block with a bandsaw to a depth of 3 mm; these formed the actual absorption boundaries. The blocks were placed at different levels from the tomographic plane, one set of scores being at a distance of 15 mm from the plane and the other set at 30 mm. The tomograph was a Polytome type U, screen film, Kodak RP, in combination with Siemens Rubin intensifying screens, was developed in a roll machine.

A linear movement directed at right angles to the scores was employed. The contour period for the scores always lay in the middle of the exposure, which means that all scores would have been sharply depicted if they had been situated in the tomographic plane. The first tomogram was obtained at 40 kV with an angle of 15°. The second tomogram was taken at the same potential and density, but the angle was increased to 45°. The third tomogram was obtained at 40 kV

boundaries Only if the movement of one such point during the whole exposure is within the limits of tolerable un harpness for a contour may no important change in the corresponding contour, as regards form or relative position in the tomogram be expected What has been called the tomographic zone in this in vestigation i e the zone from which only true contours may ari e is actually the same as POSCHL meant when he discussed the section thickness of the tomogram Thus the factors he described as influencing section thickness in fact affect the width of this zone of true depiction contours may however ari e from ab-orption boundaries outside the tomographic zone the vi ibility of both types of contour being only in an indirect way determined by the total movement of the tomographic system

Exposure regulating devices have come into common use in conventional roentgenography during the last decade These are con tructed o as to break the anode current of the roentgen tube when a certain roentgen do e has reached the film thus regulating the exposure time The ame principle is not applicable in tomography ince the time cannot be changed although similar dose regu lating devices may be employed

Since the exposure time as well as the anode potential are fixed the only fac tor left for regulation is the amperage A permeable photo cell inserted im mediately above the film can regulate the anode current in such a way as to bring about a constant dose rate onto the film during the whole tomographic expo ure Ab orption boundaries depicted by attenuated radiation (Fig 3) will undergo a greater reduction in visibility compared with those produced by a more intense roentgen beam With the do e rate at the film level kept con tant however the influence of structures not themselves represented may be counter acted This may be of importance in many tomographic examinations When the middle ear and inner ear are examined the roentgen beam will pass along the base of the skull during part of the exposure the contours then formed having a much lower visibility than those produced when the roentgen beam passes at greater angles

Acknowledgement

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SUMMARY

A theoretical and a practical investigation of tomographic blurring is presented The earlier theories are considered and a modification suggested The value of exposure regulating devices in keeping the dose rate to the film constant is discussed

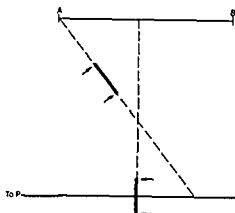


Fig 5

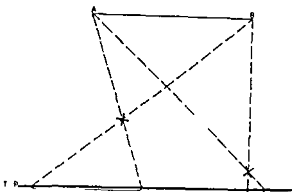


Fig 6

Fig 5 Tomography of two absorption boundaries (arrows) The upper absorption boundary is depicted when the focus is at A the corresponding contour being spurious this is situated to the right of the true contour from the other absorption boundary thus indicating a false position of the upper absorption boundary

Fig 6 Tomography of two points in different absorption boundaries The movement on the tomographic plane during the exposure is indicated by braces Assuming that the motion of the right point equals the tolerable blur the corresponding absorption boundary can never be represented by a spurious contour of false form or position The point marks the upper limit of the tomographic zone The absorption boundary to which the other point belongs may be depicted at such different sites so that false forms and positions may be encountered This means that the contour will be spurious due to the fact that its movement is so large as to be evident to the naked eye

tomograph had not had certain imperfections in depiction The contours were therefore regarded as artefacts The imperfections in question were those included under the heading 'angular variations in the intensity of the roentgen beam

The term spurious contour implies that false conclusions as to the nature of the object may be drawn from an examination of such contours unless they are recognized as artefacts It was stated earlier that a spurious contour may obtain its form not only from the shape of the absorption boundary, but also from that of the tomographic movement path Such contours may be misleading as to the location of the absorption boundaries in question relative to absorption boundaries giving rise to true contours (Fig 5) The spurious contour must have a large contour movement over the tomographic plane, this being the cause of the false location of the contour in the tomogram A definition of the limits of the tomographic zone, outside which absorption boundaries may give rise to spurious contours, demands an analysis of the movement of single points within the object during the tomographic exposure, exactly as performed by Poseitt (1940) (Fig 6) The two single points in the figure are situated in different absorption

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FREQUENCY OF BACKFLOW IN ACUTE RENAL COLIC

by

OLLE OLSSON

Backflow or reflux are terms used for extravasation of urine from the renal pelvis through a rupture at the fornical margin of one or several calyces. OLSSON (1948) in a monograph on backflow in urography described 6 patients with acute renal colic; another 7 patients were included in a paper of 1953. Many authors have since reported similar observations; these have all corroborated that backflow of this type usually occurs with severe renal colic, mostly of only a few hours duration and that the signs of urinary stasis in terms of delay of excretion on the side with backflow and dilatation of the kidney pelvis are usually only slight or moderate. Backflow as demonstrated by escape of urine outside the renal pelvis disappears fairly rapidly. Only exceptionally will backflow be demonstrable at control examinations; such exceptions have been described by OLSSON (1953), HARROW (1966), SCHWARTZ et coll. (1966), BONK et coll. (1966).

The frequency of backflow in acute renal colic is controversial and important. The importance is based on the fact that backflow may produce clinically noticeable changes in connection with the actual attack and may also form the basis for late lesions with reactive tissue proliferation in the sinus of and outside the kidney (FAJERS & IDBOHRN 1957), perinephritis (HARROW 1966) and eventually retroperitoneal fibrosis. This phenomenon was encountered in 5 patients in

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ZUSAMMENFASSUNG

Eine theoretische und praktische Untersuchung der Unschärfe bei der Tomographie wird vorgelegt. Die bisherigen Theorien werden dargelegt und eine Abänderung vorgeschlagen. Der Wert von Expositions regulierenden Anordnungen, um die Dosisrate zum Film konstant zu halten, wird diskutiert.

RÉSUMÉ

L'auteur présente un travail de recherche théorique et pratique sur le flou tomographique. Il étudie les théories existantes et en propose une modification. Il étudie l'intérêt de dispositif régularisant l'exposition en maintenant un débit de dose constant au niveau du film.

REFERENCES

EDHOLM, S.: The tomogram. Its formation and content. Acta radiol. (1960) Suppl. No. 193.

KIEFFER, J.: Analysis of laminagraphic motions and their values. Radiology 33 (1939), 560.

MORGAN, R. H.: Visual perception in fluoroscopy and radiography. Radiology 86 (1966), *403*.

POSCHL, M.: Untersuchungen über das tomographische Bild. I. Teil der Arbeit Tomo raphie des Schädels. Fortschr. Röntgenstr. 62 (1940), 33.

REICHMANN, S.: Development of spurious contours of spherical and cylindrical objects in tomography. Acta radiol. Diagnosis 12 (1972), 317.

ROHLER, R.: Informationstheorie und Radiologie. Ärztl. Forsch. 16 (1962), 108.

SCHOBER, H.: Anwendbarkeit der Informationstheorie auf Probleme der Röntgendiagnostik. Ärztl. Forsch. *16 (1962), 103*.



Fig 2 Case 2 Renal colic Some sinus back flow at lower calyces

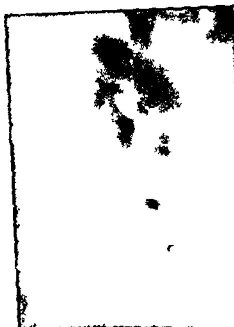


Fig 3 Case 3 Renal colic Slight delay in excretion with dilatation of renal pelvis. Some sinus backflow with filling of lymphatics from middle calyx.

a large extravasation with a course completely different from those observed earlier Two patients had only small extravasations but in 3 they were large and diminished rapidly These 5 patients will be described in detail

Case 1 Female aged 68 operated upon six years previously for a right renal calculus with a history of severe *pain for a few hours before examination* The right kidney was irregular with a large indentation in the lateral surface *small calculi lay in the lower part of the kidney and one calculus in the lower part of ureter* Urography (Fig 1) Slight delay in excretion but good concentration of contrast medium with moderate dilatation of renal pelvis this was deformed by old papillary necroses with dilated calyces extending to the capsule in the upper and middle parts of the kidney Early in the examination contrast medium was escaping from the *uppermost calyx to the* extrarenal space laterally this escape increased rapidly and contrast medium was *oozing into* the perirenal space down *to the* lower pole of the kidney and *extending laterally* This illustrates a hitherto un reported localization and mode of extension of backflow

Case 2 Male aged 40 with three *hours of* sharp pain on the left side diminishing at time of examination Urography (Fig 2) Small *calculus in middle of left ureter* Slight delay in excretion Some dilatation of renal pelvis and good concentration of contrast medium Slight extravasation around *lower calyces of left kidney* but no spread.

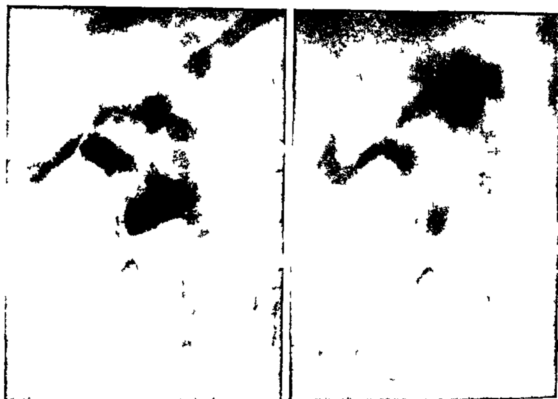


Fig. 1. Case 1. Renal colic. Small right kidney with marked pyelonephritic changes. Slight delay in excretion with some dilatation of the renal pelvis. Large extravasation laterally from upper calyx spreading extrarenally to lower pole of kidney.

150 acute urographies (OLSSON 1948). SCHWARTZ et coll. (1966) reported 13 patients with the type under discussion in 256 urographies, or 5 per cent. HARROW & SLOAN (1961) in describing two patients stated "Extravasation into the renal sinus is probably common during acute renal colic" and HARROW emphasized this in a later paper. Several publications, for example by SENGPIEL (1957), POLITANO (1957), FINE & VERMOOTEN (1960), AHLGREN (1967), BRIJS (1968), SMULEWICZ et coll. (1970) etc. suggested on the other hand that the process is a rare phenomenon.

The reported frequency of backflow is naturally related to the possibility of observing extravasation. The type of backflow in connection with acute renal colic and the extent of the backflow and its course must first be considered.

Types of backflow. The first series of 6 and the second series of 7 patients (OLSSON 1948, 1953) all represented large extravasations extending through the hilum and out into the perirenal and periureteral spaces. Several other instances of this type have also been reported (e.g. SMULEWICZ 1970). In the present series various types of backflow have been encountered. One patient had



a b

ˈg 5 Ca e 5 Re al oli a) Ruptu e of fornix of u per cal x with larg extrava ation along onfl ent part of renal pelvis through h lum and down the ureter l) Thirty minutes later nly sn all traces of extravasation

upper calyx pread in the sinus along the confluence area of the renal pel is to escape through th hil m of the kidney and extend d wn along th uret r Only slight extravasa tion was apparent at the margin of the upper calyx 30 minutes later some lymphatics from the calyces in the lower half of the kidney were now filled

Ca es 2 and 3 of the eries di close that the roentgenologically demonstrable backflow may be fairly small and restricted to the immediate vicinity of the calyceal edges Lymphatics may be filled in the proce s of draining such an extra va ation Ca.es 4 and 5 indicate that a large extravasation may dimini h or di appear o that in a hort period it may alter its appearance and become barely



Fig. 4. Case 4. Renal colic. a) Large backflow. b) Fifty minutes later only small amount of extravasated urine remains.

Case 3. Male, aged 57, with a few hours of sharp pain in left flank. Pain only slight at time of examination; no calculus evident. Urography (Fig. 3): Slight delay in excretion on left side, good concentration of contrast medium, dilatation of renal pelvis and some pyelonephritic changes. Minor extravasation at margins of several calyces in middle and upper part of kidney and filling of lymphatics.

Case 4. Male, aged 34, with a few hours of sharp pain on right side. Urography (Fig. 4): Small stone at lower end of right ureter. Moderate delay in excretion, good concentration of contrast medium, and slight dilatation of renal pelvis. A large extravasation was evident 16 minutes after injection of contrast medium; only slight traces of the large extravasation were apparent 50 minutes later when the pelvic dilatation had disappeared but leaving the ureter filled.

Case 5. Female, aged 72, with a history of right nephrectomy for carcinoma two years previously and six hours of sharp pain on left side for six hours before examination. Urography (Fig. 5): Slight delay in excretion, good concentration of contrast medium and slight dilatation of renal pelvis. Large extravasation evident; this started at the brim of the



Fig 6 Case 6 Renal colic At first no excretion on right side slight pain Further attack of pain nineteen minutes after injection of contrast medium Good excretion and slight dilatation on right side Fornix rupture and sinus extravasation in lower part of kidney The calyx is projected in an axial direction and the extravasation forms an irregular halo around the calyx

ureteric compression applied after a second injection of contrast medium in a further 25 patients Extravasation again never occurred

Repeat urography was performed a few days later in most patients with ureteric calculus and stasis and if the latter had disappeared with compression No patients in this large group without acute extravasation had extravasation of the type under discussion Two patients merit special mention in this connection

Case 6 Male aged 37 with severe pain for a few hours on the right side Urography (Fig 6) Small calculus at lower end of right ureter Delayed excretion of contrast medium with low concentration on the affected side The patient had a sharp attack of pain 19 minutes after the injection of the contrast medium Good excretion of urine was evident on the affected side in a film 8 minutes after the onset of the attack the renal pelvis was moderately dilated and reflux was evident from a fornical angle in the lower part of the kidney with extravasation into the sinus and through the hilum Urography two weeks later was normal

Case 7 Female aged 63 with a sharp attack of pain on the left side of a few hours duration Urography (Fig 7) Calculus at lower end of left ureter Good renal function with moderate dilatation of left renal pelvis and calyces Pain occurred 12 minutes after the injection of the contrast medium and four minutes later rupture occurred in the fornices of the middle calyces of the kidney with moderate backflow to the sinus Three minutes after this the ureter was completely outlined and the extravasation had practically disappeared Urography six days later was normal

detectable. A small extravasation or a slight pyelolymphatic backflow may thus reflect either an early or a late stage of considerable extravasation.

This series thus reveals that the backflow phenomenon in acute renal colic where the passage is blocked by calculus, basically follows the series of events in backflow in urography when the ureteric flow is obstructed by compression (OLSSON 1948). The difference is not a qualitative one but one related to pressure gradients. The dramatic pressure effect in a sharp attack of renal colic is illustrated by the often wide escape of the contrast medium extrarenally. This phenomenon is well illustrated by Case 1.

The types, and especially the extent, of the backflow may naturally influence its detectability and thus any opinion on its frequency. The course of the phenomenon with rapid disappearance of large extravasations may have a corresponding effect. The cases thus disclose that the frequency of backflow depends upon the stage of the acute attack in which the patient is examined and even the recording intervals during the actual examination. Large extravasations may be absorbed so rapidly that they escape recording if — as is usual in the later stages of an acute urography — the intervals between single films are long. Estimation of the frequency of backflow may also be disturbed by the conditions at the actual examination.

Examination conditions. The examination conditions, as is often the case in emergency examinations, are hampered from the first by non-preparation of the patient and, in this type of examination, by the absence of cooperation of a patient in pain. The less obvious changes may thus escape detection.

Excretion of contrast medium must occur from the kidney in colic if an extravasation is to be detected. Patients referred for emergency urography may be divided into three roughly equally large groups. One with ordinary excretion conditions and no or only slight dilatation of the renal pelvis and the ureter, representing mainly examination after the pain has completely or almost completely subsided. In a second group delay of different degrees in excretion of the contrast medium is registered together with slight to marked dilatation of the renal pelvis and the ureter. The third group consists of patients with no excretion on the affected side or with the excretion much delayed and, when observable, a low concentration of urine. No extravasation occurs for obvious reasons in the last group, or indeed in the first group. Extravasation is thus evident only in the second group; the concentration of urine in this group is however often low and in association with bowel masking will make extravasation impossible to observe.

Many patients in the third group (no excretion) have been followed for a considerable time until excretion ultimately occurred. However, extravasation has never been observed. The dosage was augmented in 25 patients and light

Certain simple facts indicate that the backflow may be a function of conditions for rapid pressure increase. The production of urine is low during the night and in the early morning hours increases considerably. Five of the original 6 patients described in the first paper had pain in the early morning. Fourteen of the 15 patients referred to had short histories and 12 of these were examined during the hours of 08.30 to 11.00.

Reflux thus occurs mainly in connection with severe attacks of pain with short duration of the attacks and under conditions in which a rapid build up of sequences leading to over distension of the urinary tract is present. RISHOLM (1954) stated that the essential cause of pain in renal colic is increased pressure in the pelvis with great variations in relation to the pain threshold. Sensation of pain is related to the mode of production of pressure, a rapid rise producing more pain at lower pressure levels than a slow rise (KILL 1957). Obstruction of the ureter causes an increase in the renal pelvic pressure which when balancing excretion pressure produces cessation of function. The refractory period between the establishment of a block and the cessation of function varies for several reasons. An increase in the pressure and an increase in the tone of the wall of the renal pelvis and the ureter are during this period concurrent. The pressure as reported originally in animal experiments by CUYON (1892) and HUBER (1895) within a few hours gradually falls. All these facts illustrate a good correlation between the physiology of pain and renal colic and the clinical and roentgenologic observations. They also stress the high degree of variability in the phases of the course of events.

Further patients with large extravasations of the type originally described have been encountered during the last year. Fifteen patients had this condition in a material of approximately 300 acute urographic examinations or about 5 per cent, the same percentage as reported by SCHWARTZ et coll. These figures are however of limited value.

HARROW (1966) in a discussion on the frequency of spontaneous extravasation of urine associated with renal colic stated "there can be no doubt about the common occurrence of perirenal extravasation even if not demonstrated on roentgenograms". He continued "before the last decade such incidences of urinary extravasation outside the renal pelvis were not diagnosed because of lack of knowledge of the roentgenographic characteristics, lesser number of excretory urographies performed in renal colic, decreased density of urographic media, less tendency to take delayed roentgenograms and inadequate amounts of injected contrast agents".

The above facts suggest that reflux in acute renal colic is an isolated occurrence and the product of several concomitant factors. They also contradict the assumption that backflow is a common phenomenon. Support for any of the

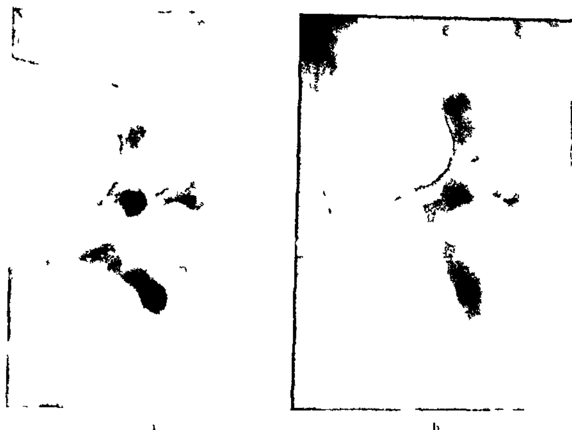


Fig. 7. Case 7. Renal colic. a) No pain or delay in excretion. Some dilatation on left side. b) Twelve minutes after injection of contrast medium further pain. Four minutes later rupture of middle calyces with moderate backflow to sinus.

The series of events in Case 6 was probably as follows. A ureteric stone caused distension and pain and the increased pressure produced cessation of renal excretion and relief of pain. A further increase in pressure engendered by the diuretic effect of the contrast medium at urography brought about renewed pain and fornix rupture; the latter in turn lowered the intrapelvic pressure, which made excretion possible with the demonstration of rupture and escape of urine from the renal pelvis. Diuresis caused by the contrast medium in Case 7 caused incompensation in drainage, rise in pressure and rupture, with escape of urine. Backflow in these two cases thus occurred directly in connection with a second attack of renal colic after the first attack had ceased; the attack started 12 and 19 minutes, respectively, after the injection of the contrast medium. WINTON (1934) in experiments in dogs reported that the normal maximal excretion pressure was approximately 30 ml Hg but with certain diuretics could be brought up to 70 ml. The contrast medium may be considered a powerful diuretic.

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Reflux thus occurs mainly in connection with severe attacks of pain with short duration of the attacks and under conditions in which a rapid build up of sequences leading to over distension of the urinary tract is present. RISHOLM (1954) stated that the essential cause of pain in renal colic is increased pressure in the pelvis with great variations in relation to the pain threshold. Sensation of pain is related to the mode of production of pressure, a rapid rise producing more pain at lower pressure levels than a slow rise (KIIL 1957). Obstruction of the ureter causes an increase in the renal pelvic pressure which, when balancing excretion pressure, produces cessation of function. The refractory period between the establishment of a block and the cessation of function varies for several reasons. An increase in the pressure and an increase in the tone of the wall of the renal pelvis and the ureter are during this period concurrent. The pressure as reported originally in animal experiments by GUYON (1892) and HEFER (1895) within a few hours gradually fall. All these facts illustrate a good correlation between the physiology of pain and renal colic and the clinical and roentgenologic observations. They also stress the high degree of variability in the phases of the course of events.

Further patients with large extravasations of the type originally described have been encountered during the last year. Fifteen patients had this condition in a material of approximately 300 acute urographic examinations or about 5 per cent, the same percentage as reported by SCHWARTZ et coll. These figures are however of limited value.

HARROW (1966) in a discussion on the frequency of spontaneous extravasation of urine associated with renal colic stated "there can be no doubt about the common occurrence of perirenal extravasation even if not demonstrated on roentgenograms". He continued "before the last decade such incidences of urinary extravasation outside the renal pelvis were not diagnosed because of lack of knowledge of the roentgenographic characteristics, lesser number of excretory urographies performed in renal colic, decreased density of urographic media, less tendency to take delayed roentgenograms and inadequate amounts of injected contrast agents".

The above facts suggest that reflux in acute renal colic is an isolated occurrence and the product of several concomitant factors. They also contradict the assumption that backflow is a common phenomenon. Support for any of the



Fig. 8. Case 8. Eight days after attack of renal colic without excretion on left side. Marked changes in shape of left renal pelvis suggesting fibrolipomatosis.

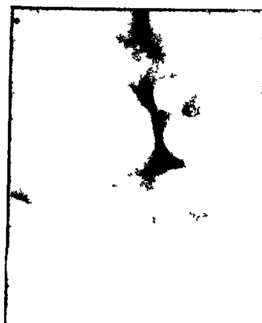


Fig. 9. Case 9. Twelve days after attack of left renal colic. Marked changes in shape mainly of confluent part of left renal pelvis of fibrolipomatosis type.

reasons given by HARROW for the non-diagnosis of a supposed high incidence of reflux is thus not forthcoming. Extravasation of minor degree or of short duration may, however, occur at a higher rate.

There is one additional roentgenologic fact that lends support to an opinion that backflow may be more common than believed. The frequency of fibrolipomatosis (OLSSON & WEILAND 1963). FAJERS & IDBOHRN (1957), OLSSON (1953, 1962) and VOEGELI (1971) have stated that backflow by causing proliferation of connective tissue and fat in the sinus may lead to angiographically demonstrable late changes. Patients after an attack of renal colic have sometimes had changes suggesting fibrolipomatosis on the side of stasis. The material is not yet ready for closer analysis but two examples will be presented.

Case 8. Male, aged 69, with left-sided renal colic for a few hours. Urography (Fig. 8): Large calculus at upper end of left ureter. No excretion. Twenty-four hours later the stone lay in the lower end of the ureter. *Excretion was now evident. Moderate* dilatation of the renal pelvis. No backflow. Repeat examination eight days later. No stasis but marked changes in shape of left renal pelvis of the fibrolipomatosis type. Urography five months later: Same conditions.

Case 9 Male aged 69 with left renal colic Urography (Fig 9) Calculus at lower end of left ureter Marked delay in excretion decrease in concentration dilatation on left side and possibly small extravasation from the edge of lower calyx Examination 12 days later Stone no longer evident No stasis Marked changes in shape of left renal pelvis suggesting fibrolipomatosis

Conclusions

Radiologically demonstrable backflow in acute renal colic appears to occur in as many as 5 per cent of urographies during or immediately after an attack of renal colic This is a minimum since examination conditions with incomplete cooperation of the unprepared patient and often with decrease in the concentration of urine may lead to it being missed, this is particularly likely should the extravasation be small or be large but rapidly disappear This assumption is further supported by findings of changes of the renal fibrolipomatosis type at urography some time after the renal colic This may be a result of tissue reaction to extravasated urine this extravasation may have occurred outside the period of observation or may have been too small to have been detected

SUMMARY

The frequency of backflow in acute renal colic as evident from the possibility of observing extravasation of urine at urography is described Seven characteristic cases are presented Backflow appears to occur in at least five per cent of cases The significance of appearances suggesting renal fibrolipomatosis after the renal colic is discussed

ZUSAMMENFASSUNG

Die Haufigkeit des Ruckflusses bei einer akuten Nierenkolik wie sie durch die Moglichkeit der Beobachtung einer Extravasation von Urin bei der Urographie zutage tritt wird beschrieben Sieben charakteristische Falle werden dargestellt Ein Ruckfluss scheint in mindestens funf Prozent der Falle vorzukommen Die Bedeutung dieser Erscheinungen die eine renale Fibrolipomatose nach der Nierenkolik vermuten lassen wird besprochen

RÉSUMÉ

L auteur etudie la frequence du reflux dans la colique nephretique aigue demontre par la possibilite d observer une extravasation d urine au cours de l urographie Il en presente sept cas caracteristiques Le reflux parait se produire dans au moins cinq pour cent des cas Il discute l interet des images qui font penser à une fibrolipomatose renale apres la colique nephretique



Fig. 8. Case 8. Eight days after attack of renal colic without excretion on left side. Marked changes in shape of left renal pelvis suggesting fibrolipomatosis.

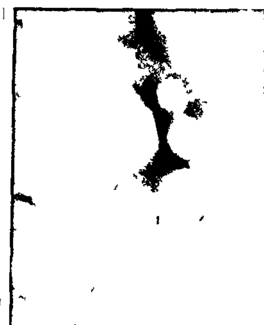


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CORTICAL VOLUME OF THE NORMAL HUMAN KIDNEY

Correlated angiographic and morphologic investigations

by

V Hegedüs and P Faarup

An appropriate method of estimating the amount of the renal cortex does not exist Several authors have relied upon a planimetric evaluation of the total kidney parenchyma at urography a method based upon a p films only, neither quantitative angiographic nor morphologic investigations of cortical volume appear to have been attempted

Angiographic examinations to estimate the in vivo thickness of the cortex in different areas of the kidney were therefore performed to determine the cortical volume and its variations in normal kidneys Correlation of the roentgenologic measurements with autopsy kidneys corrected for volume changes post mortem were necessary The renal cortex usually forms a smooth surface at the periphery but a highly irregular one towards the medulla the fatty tissue in the sinus and towards the pelvis These irregularities represent the internal portion of the cortex called the columns of Bertin The present roentgenologic measurements were confined to the superficial continuous cortical mass (hereafter called cortex) (Figs 2 4) the contribution of the columns of Bertin to the total cortical volume could not be measured and has been quantitatively determined in autopsy kidneys only (Fig 1)

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REFERENCES

AHLGREN P Renal uroplani Pyelosinos refluks (In Danish) Nord Med 77 (1967) 469
BONK J P VASCH R I and CHERIS D N Spontaneous rupture of the renal pelvis Amer J Roentgenol 98 (1966) 54
BRIJS A Extravasate bei intravenoser Urographie Fortschr Rontgenstr 109 (1968) 375
FAJERS C M and IDBOHRN H Peripelvic reflux simulating a tumour of the renal pelvis Urol int (Basel) 5 (1957) 197
FINE M G and VERMOOTEN V Spontaneous extravasation associated with excretory urography J Urol 84 (1960) 109
GUYON F Influence de la tension intra rénale sur les fonctions du rein C R Acad Sci (Paris) 114 (1892), 457
HARROW B R Spontaneous urinary extravasation associated with renal colic causing a perinephric abscess Amer J Roentgenol 98 (1966) 47
— and SLOAN J A Pyelorenal extravasation during excretory urography J Urol 85 (1961) 995
HUBER A Recherches physiologiques sur la résorption rénale Thèse Paris 1895
KIIL F The function of the ureter and renal pelvis W B Saunders London and Philadelphia 1957
OLSSON O Studies on backflow in excretion urography Acta radiol (1948) Suppl No 70
— Backflow in excretion urography during renal colic *In* Modern trends in diagnostic radiology Edited by J W McLaren Butterworth London 1953
— Encyclopedia of urology Springer Verlag Heidelberg 1962
— and WEILAND P O Renal fibrolipomatosis Acta radiol Diagnosis 1 (1963) 1061
POLITANO V A Pyelorenal backflow clinical significance and interpretation J Urol 78 (1957) 1
RISHOLM L Studies on renal colic and its treatment by posterior splanchnic block Acta chir scand (1954) Suppl No 184
SCHWARTZ A CAINE M HERMANN G et coll Spontaneous renal extravasation during intravenous urography Amer J Roentgenol 98 (1966) 27
SENGUL G Renal backflow in excretory urography Amer J Roentgenol 78 (1957) 289
SMULEWICZ J DORFMAN J GAGAN S et coll Spontaneous rupture of the collecting system of the kidney an evaluation J Urol 104 (1970) 507
VOIGTEL F Die Pathogenese der Fibrolipomatose Radiologe 11 (1971) 209
WINTON F The relation between diuresis and maximum ureter pressure and its bearing on current methods of estimating the rate of glomerular filtration J Physiol 83 (1934) 38

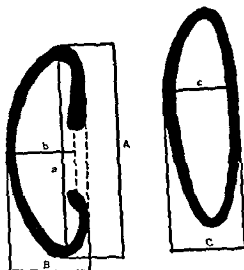


Fig 2 Method of measurement of cortical volume at angiography The distances A B and C represent the length width and thickness of the kidney a b and c the same parameters for the internal ellipsoid body including columns of Bertin medulla sinus and pelvis

Methods and Material

Roentgenologic method and material

HEGEDUS (1972) has described the technique for the three dimensional angiographic examination of the kidney as well as a method for the estimation of the roentgenologic renal volume the latter method has again been employed

The thickness of the cortex This was measured in the a p projection at the upper and lower poles of the kidney the lateral border and between the two hilar lips with two construction lines the average thickness of the hilar lips being taken as a gauge (Fig 1a) The cortical thickness ventrally and dorsally was measured in the lateral projection (Fig 1 c)

The volume of the cortex The total renal volume was estimated according to the formula for the volume of an ellipsoid body $\frac{A\ B\ C\ \pi}{6}$ where A and B are the length and width of the kidney measured in the a p projection and C the thickness in the lateral projection (Fig 2) These three axes are at right angles to each other and represent the maximum length in all three dimensions The volume of the smaller ellipsoid body beneath the cortex was then calculated with the same formula where the parameters a b and c are measured in the same way as A B and C This smaller ellipsoid body comprises the columns of Bertin the medulla, the sinus and the pelvis The volume of the

a b c



d

Fig. 1. a) Angiogram of a right kidney, a.p., in the arteriolo-capillary phase. Points of measurement of the cortical thickness indicated. b) An autopsy kidney sectioned as in (a) for comparison. c) Same as (a), lateral projection. Points of measurement of the cortical thickness indicated. d) An autopsy kidney sectioned as in (c) for comparison. The cortex and columns of Bertin are identifiable.

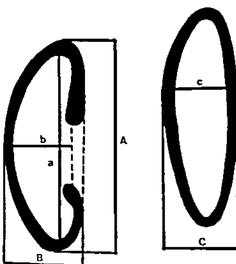


Fig. 2. Method of measurement of cortical volume at angiography. The distances A, B and C represent the length, width and thickness of the kidney and a, b and c the same parameters for the internal ellipsoid body including columns of Bertin, medulla, sinus and pelvis.

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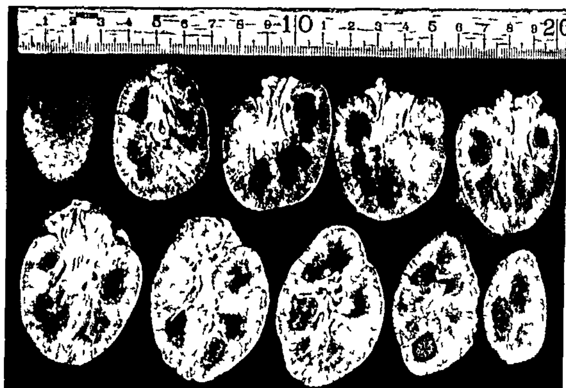


Fig. 3. Human kidney fixed in formalin and divided into 1 cm parallel sections cut transversally to the longitudinal axis. The cortex, the columns of Bertin, the medulla and the pelvic fraction are identified in the sections (cf. fig. 1).

smaller ellipsoid was subtracted from the total renal volume to give the volume of the cortex. The measurements were made in the films in which the cortex is most prominent, i.e. in the arteriolo-capillary or in the nephrographic phases.

The 86 kidneys examined were each supplied by only one artery and had no clinical nor roentgenologic changes. None of the patients had hypertension but 41 patients had changes in the contralateral kidney, while in 12 patients both kidneys were normal. The age of the patients varied between 12 and 76 with a slight predominance of the group between 25 and 60 years of age. The material comprised 43 men and 10 women (50 right and 36 left kidneys).

Morphologic methods and material

Autopsy kidneys. This material comprised 16 kidneys from 8 human autopsies. The cases, aged from 10 to 70 years, had no history nor clinical or laboratory signs of kidney disease or hypertension. The kidneys were each supplied by one artery. Microscopy confirmed the absence of pathologic parenchymal changes.

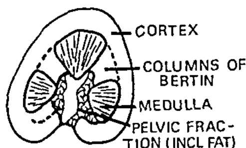


Fig 4 The fractions investigated as measured by planimetry of sections from human kidneys fixed in formalin

The kidneys were fixed in neutral formalin 10 % for at least 4 days when the total volume of each was determined according to the principle of Archimedes No systematic decrease in volume was evident in the autopsy kidneys during the fixation in formalin Each kidney was then sectioned at right angles to the vertical axis into 1 cm parallel cuts (Fig 3) The slices were photographed planimetry performed and the following fractions separated (Fig 4) (1) Total cortical volume divided into (a) renal cortex without columns of Bertin and (b) columns of Bertin, (2) medulla and (3) pelvic fraction (kidney pelvis and fat tissue in the sinus)

Rat kidneys Eight normal albino rats weighing 200 g were anaesthetized with Nembutal The left kidney was carefully isolated in the abdomen and rapidly transferred to a watchglass and weighed The bleeding and the elimination of the tubular and the interstitial fluid through the renal vein having stopped (LEYSSAC 1966) the weight was again determined and the perirenal fatty tissue — being included at the rapid removal of the kidney from the animal — was removed and its weight subtracted from the kidney weight The percentage decrease in the renal volume was thus measured in the early post mortem period (Table 1) The kidney weights were taken as a measure of their volumes (MOELL 1961)

In addition the left kidney in 4 rats of the same weight and similarly anaesthetized was rapidly frozen in isopentane at —165 C and histologic sections cut tangentially to the surface of the kidney These were freeze-dried, stained by osmic acid vapour and mounted in liquid paraffin as previously described (FAARUP et coll 1971) (Fig 5) Similar tangential sections of the cortex from the formalin fixed right kidney of the animals were prepared and PAS stained (FAARUP & PETRI 1969) (Fig 6)

The decrease in the cortical volume of the 4 kidneys from each group was estimated by counting the number of tubules in identical areas in the histologic sections The post mortem cortical shrinkage was thus easily determined (Table 2)

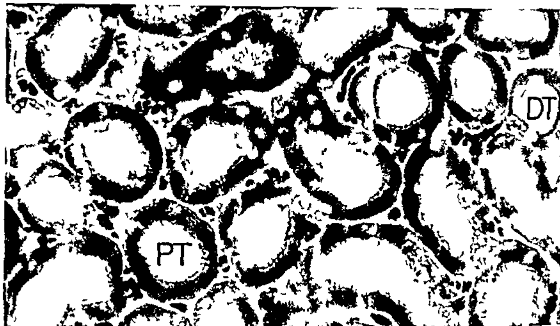


Fig 5 Freeze dried cryostat section from instantly frozen rat kidney cortex cut tangential to the surface and stained by osmic acid vapour Both proximal tubules (PT) and distal tubules (DT) are open and contain fluid the many intertubular capillaries are recognized by the erythrocytes in their lumina Much interstitial tissue is present This preparation depicts the morphology of the functioning kidney cortex × 875



Fig 6 Rat kidney fixed in formalin in which the section is made tangential to the surface of the cortex as in fig 5 Post mortem changes occlude most of the tubules with nearly all the capillaries drained of blood collapsed and unidentifiable the interstitial tissue is diminished A significant decrease in the cortical volume compared with the morphology of the functioning kidney is evident (cf fig 5) (Symbols as in fig 5) PAS stain × 875

Table 1

Early post mortem total volume shrinkage in rat kidneys weighed on removal and again ? minutes later after drainage of blood tubular and interstitial fluid (cf figs 5 6)

Kidney No	Kidney weight (g)		Shrinkage (%)
	At removal	After removal	
1	0 868	0 689	21
2	0 857	0 720	16
3	0 780	0 568	27
4	0 832	0 633	24
5	0 902	0 666	26
6	0 945	0 683	27
7	0 940	0 676	28
8	0 971	0 716	24
Mean			24

Table 2

Post mortem shrinkage of the renal cortex in 8 rat kidneys The number of tubules in freeze-dried tissue was compared with the number in formalin fixed tissue in identical cortical areas from sections as in figs 5 and 6

Kidney No	Freeze dried tissue	Kidney No	Fixed tissue	Shrinkage (%)
1	38	5	64	
2	42	6	74	
3	43	7	73	
4	43	8	76	
Mean	42		72	42

Results

Roentgenologic results

The thickness of the cortex The linear measurements of the cortical thickness at the poles at the lateral and the medial borders of the kidney and at the dorsal and ventral surfaces are presented in Fig 7 The mean value of the measurements indicates that the thickest cortical layer generally lies at the upper pole and at the medial border of the kidney while the cortical layer is somewhat thinner at the lower pole and thinnest at the ventral and the dorsal surfaces No significant side or sex differences were apparent

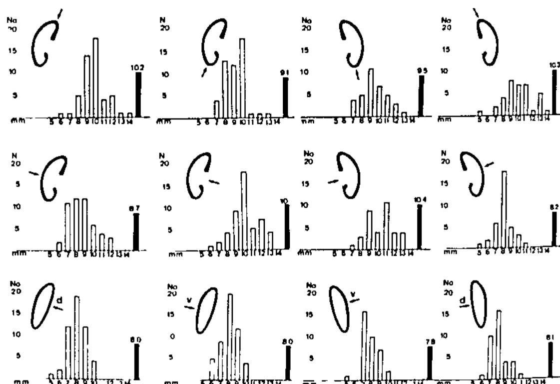


Fig. 7. Linear measurements of the cortical thickness at angiography. The sites of measurements (v = ventrally, d = dorsally) are indicated (arrows), the filled columns representing mean values at each site of kidneys.

The absolute and the percentage volume of the renal cortex. The roentgenologic volume of the cortex at different ages appears in Fig. 8. The magnification factor and the error arising from the geometric formula were ignored. As stated previously (HEGEDUS 1972), the total of errors with these measurements as compared to the in vivo conditions gives a magnification of approximately 50 volume per cent. The results of the roentgenologic measurements and the values corrected to the in vivo conditions are presented in Table 3.

No statistic relationship was evident between the volume of the cortex and side, age or sex ($r = 0.214$).

The volume of the cortex of each kidney is related to the total renal volume in Fig. 9. The relationship is fairly constant and varies between 50 and 60 per cent with a few values above and below this range ($SD = 4.15$). The mean value is 54 per cent, with no significant side difference. The 9 kidneys with a volume of the cortex less than 50 per cent all had numerous and large columns of Bertin (Fig. 10). The kidneys with more than 60 per cent cortex had few and small columns of Bertin (Fig. 11). No relation between age, sex, side and the volume of the cortex was evident.

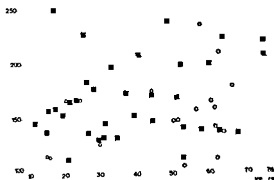


Fig. 8. Volume of cortex as measured at angiography (without correction for magnification) compared to age. The volume varies between 100 and 250 ml with a mean of 162 ml which after correction for magnification becomes 81 ml. No relationship between age and volume of the cortex was evident. O right ■ left kidneys.

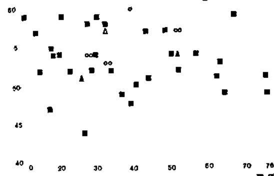


Fig. 9. Volume of cortex expressed as percentage of the total renal volume related to age as measured at angiography. The volume usually varies between 50 and 60 per cent in most kidneys. O right Δ two right ■ left ▲ two left kidneys.

Morphologic results

Autopsy kidneys. The total volume of the kidneys measured as described is given in Fig. 12 and the volume distribution between total cortex, medulla and pelvic fraction in Fig. 13. The cortical volume was further divided into the volume of the cortex and that of the columns of Bertin (Fig. 14). The percentage

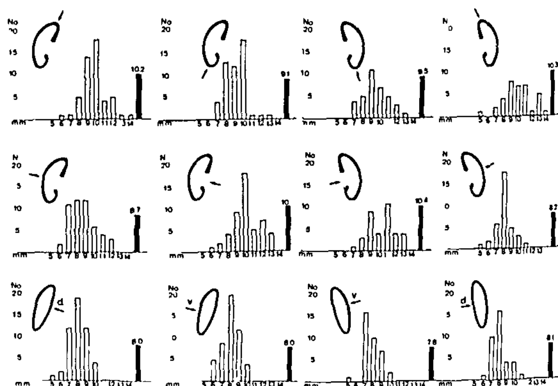


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Fig 10 A kidney with low volume of cortex (46 per cent) Great number of large columns of Bertin a) a p b) lateral

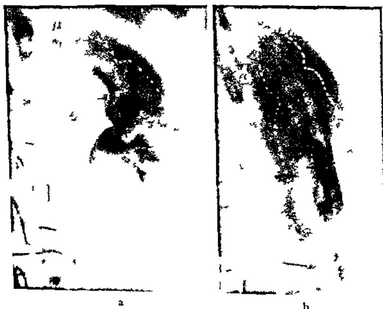


Fig 11 A kidney with large volume of cortex (62 per cent) Few and small columns of Bertin a) a p b) lateral

Table 3

Minimum, maximum and mean values of total renal volume, for non-cortical fraction with columns of Bertin and cortical volume as measured at angiography. The measured values are twice as great as those corrected to correspond to conditions in vivo

	Without correction			With correction			Mean (%)
	Minimum (ml)	Maximum (ml)	Mean (ml)	Minimum (ml)	Maximum (ml)	Mean (ml)	
Total volume	172	475	303	86	238	152	100
Total non-cortical fraction and columns of Bertin	72	205	141	36	103	71	46
Cortical volume	*100*	*270*	*162*	*50*	*135*	*81*	54

contribution of the total cortical volume to the total kidney volume was fairly constant, the volume of the two cortical fractions were, however, inversely related (Table 4).

Rat kidneys. The total decrease of the renal volume as expressed in weight during the first two minutes following the disruption of the blood supply is given in Table 1. It appears that the mean decrease in volume was 24 per cent. No further volume changes in the kidneys occurred during the fixation that followed.

The cortical volume changes in the rat kidney were estimated in tangential microscopic sections in the renal cortex (Figs. 5, 6). The values appear in Table 2. The mean cortical decrease in volume was 42 per cent which was much greater than the decrease of the total kidney volume (mean 24 per cent). The post-mortem volume changes of the kidney are thus mainly localized in the renal cortex.

Discussion

The roentgenologic evaluation of the size of the renal cortex has been discussed by HODSON et coll. (1965, 1966), LUDIN (1961, 1967), KAHN (1962), VUORINEN et coll. (1962), SCHREIBER (1966) and WOJTOWICZ (1967). Conclusions have been drawn in these reports on the amount of the total renal parenchyma, invariably from two-dimensional measurements in roentgenograms. This type of calculation results in an approximation only. Morphologic investigations of the renal cortical volume do not appear to have been performed. The aim of the

Table 4

Minimum, maximum and mean values in the quantitative estimation of the different fractions measured in human autopsy kidneys fixed in formalin (cf figs 12, 13, 14)

	Minimum (ml)	Maximum (ml)	Mean (ml)	Mean (%)
Total volume	70	200	128	100
Pelvic fraction	4.6	33.4	15.3	11.9
Medulla	21.7	52.2	41.0	32.0
Total non-cortical fraction	26.3	85.6	56.3	43.9
Cortex	27.1	82.6	55.5	43.4
Columns of Bertin	6.4	31.8	16.2	12.7
Total cortical fraction	43.7	114.4	71.7	56.1

present work was to evolve a more accurate, clinically applicable method for the quantitative determination of the renal cortical volume. The roentgenologic information obtained was to be tested with a direct morphologic quantitative estimation of the renal cortical volume with due regard to the post mortem changes in the renal tissue; these changes appear to have been ignored in previous investigations. Normal kidneys were used so as to provide a basis for later clinical and pathologic research.

The angiographic method has indicated that the volumes of both the total kidney and the cortex may be obtained from three dimensional measurements *in vivo*. The latter should however be corrected for their inherent errors before they truly reflect the *in vivo* conditions. These errors mainly result from magnification, slight inaccuracy in the geometric formula and the variable situations of the kidneys in the body (HEGEDUS 1972). The total error in the present measurements produced approximately a doubling of the in vivo volume. However, since the total renal volume and the cortical volume are both measured in the same films and represent identical errors, their values are truly proportional (Fig. 9). Linear roentgenologic measurements of the cortical thickness were made in different areas of the kidney easily identified in the films to facilitate a rapid evaluation (Fig. 7).

As determined by *morphologic estimations* of the cortical volume in vivo the inherent errors appear to be due solely to post mortem volume changes. HANSEN (1960), COLLIER & SWANN (1971) and FAARUP et coll. (1971) demonstrated that post mortem changes in the renal cortex are quantitatively marked (Figs. 5, 6). These changes occur rapidly after the disruption of the renal blood flow (LEYSSAC 1966), so that the fractioned volume determinations on autopsy

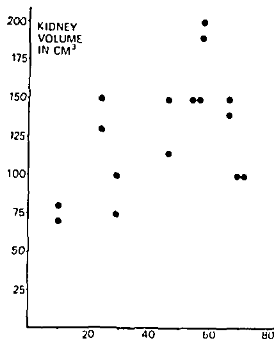


Fig 12

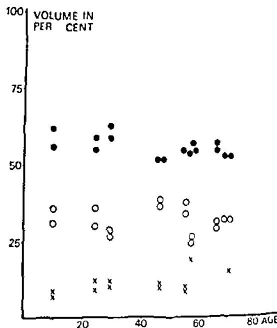


Fig 13

Fig 12 The non corrected total renal volume expressed in ml of human autopsy kidneys fixed in formalin Mean value = 128 ml

Fig 13 Non corrected volume of the cortical ● medullary ○ and pelvic × fraction in human autopsy kidneys expressed as percentages The values are approximately equal for the different ages but the pelvic fraction becomes slightly larger with increasing age due to a larger amount of fatty tissue in the sinus

Fig 14 The fractionated cortical volume in human autopsy kidneys expressed as percentage The volume of the cortex ▲ is lowest in those with the highest volume of columns of Bertin △ The two parameters are thus complementary resulting in an almost constant percentage of the total cortical volume (cf fig 13)

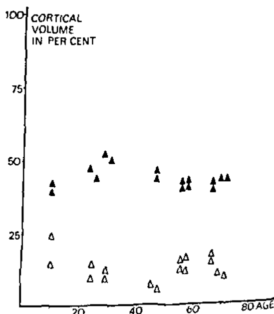


Fig 14

Table 4

Minimum maximum and mean values in the quantitative estimation of the different fractions measured in human autopsy kidneys fixed in formalin (cf figs 12 13 14)

	Minimum (ml)	Maximum (ml)	Mean (ml)	Mean ( )
Total volume	70	200	128	100
Pelvic fraction	4 6	33 4	15 3	11 9
Medulla	21 7	52 2	41 0	32 0
Total non cortical fraction	26 3	85 6	56 3	43 9
Cortex	27 1	82 6	55 5	43 4
Columns of Bert n	6 4	31 8	16 2	12 7
Total cortical fract on	43 7	114 4	71 7	56 1

present work was to evolve a more accurate clinically applicable method for the quantitative determination of the renal cortical volume The roentgenologic information obtained was to be te ted with a direct morphologic quantitative estimation of the renal cortical volume with due regard to the post mortem changes in the renal tissue these changes appear to have been ignored in previous investigations Normal kidneys were used o as to provide a basis for later clinical and pathologic research

The angiographic method has indicated that the volumes of both the total kidney and the cortex may be obtained from three dimensional measurements in vivo The latter should however be corrected for their inherent errors before they truly reflect the in vivo conditions These errors mainly result from magnification slight inaccuracy in the geometric formula and the variable situations of the kidneys in the body (HEGEDÜS 1972) The total error in the present measurements produced approximately a doubling of the in vivo volume However ince the total renal volume and the cortical volume are both measur ed in the same films and represent identical errors their values are truly proportional (Fig 9) Linear roentgenologic measurements of the cortical thickness were made in different areas of the kidney easily identified in the films to fa cilitate a rapid evaluation (Fig 7)

As determined by *morphologic estimations* of the cortical volume in vivo the inherent errors appear to be due solely to post mortem volume changes HANSEN (1960) COLLIER & SWANN (1971) and FAARUP et coll (1971) demonstrated that post mortem changes in the renal cortex are quantitatively marked (Figs 5 6) These changes occur rapidly after the disruption of the renal blood flow (LEYSSAC 1966) o that the fractioned volume determinations on autopsy

Table 5

Cortical and renal volumes with and without correction The values as corrected to correspond to conditions in vivo are approximately identical in the angiographic and in the morphologic calculations

	Calculated volume at angiography		Measured volume in autopsy kidneys	
	Without correction	With correction	Without correction	With correction
Total kidney volume	303	152	128	159
Cortical volume	162	81	56	79

kidneys (Figs 13, 14) should be corrected to conditions in vivo (Tables 1, 4) Rat kidneys were used for the estimation of the degree of the post mortem volume changes in the renal cortex Both the total renal volume changes and the isolated decrease in volume in the renal cortex were investigated with an appropriate histologic technique Contrary to the morphologic information it is recognized that the roentgenologic estimation of the volume of the columns of Bertin can only be semi quantitative The cortical volume in the morphologic part of the works was therefore further divided into the superficial, continuous cortical mass and the columns of Bertin Both examinations indicated that the contribution of the whole renal cortex to the total renal volume is in normal kidneys fairly constant Since the values obtained from the roentgenologic and morphologic investigations are about identical (Table 5), it is evident that the results of the roentgenologic measurements of the volume of the cortex actually reflect the conditions in vivo

In conclusion, it may be stated that the techniques used have produced a way of estimating the volume in vivo of the renal cortex The results presented for the normal kidneys will now form a basis for investigations of early, generalized pathologic changes in the renal cortex

Acknowledgements

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SUMMARY

A comparative angiographic and post mortem morphologic examination of the renal cortical volume has been performed The values obtained with both techniques as corrected to the in vivo conditions are in good agreement

ZUSAMMENFASSUNG

Es wurde eine vergleichende angiographische und post mortem morphologische Unter chung des corticalen Volumens der Niere vorgenommen Die mit beiden Techniken er altenen Werte auf in vivo Bedingungen korrigiert zeigten eine gute Übereinstimmung

RÉSUMÉ

Les auteurs ont fait une étude comparative angiographique et morphologique post mor em du volume du cortex renal Les valeurs obtenues par ces deux techniques corrigées ux conditions in vivo sont en bonne concordance

REFERENCES

BARGER A C Cortical and medullary blood flow in the kidney *In* Progress in pyelonephritis p 338 Edited by E H Kass F A Davis Co Philadelphia 1965

BERTIN M Mémoire pour servir à l histoire des reins Mémoires de l Academie Royale des Sciences 1744 Quoted by Hou Jensen

COLLIER R O and SWANN H G Relation of kidney size to blood pressure Amer J Physiol 220 (1971) 488

FRIEDENBERG M J BRUCE J WALZ A B et coll Roentgen size of normal kidneys a com puter analysis of 1 286 cases Radiology 84 (1965) 1022

FAARUP P and PETRI M Peroperative evaluation of the juxtaglomerular apparatus in human kidneys A rapid frozen section technique especially applicable to hypertensive patients Acta path microbiol scand 76 (1969) 326

— SAELAN H and RYO G Correlation between tubules and capillaries and size of interstitial space in the functioning rat kidney Influence of different types of preparation Acta path microbiol scand Sect A 79 (1971) 607

HANSSEN O E Early post mortem renal changes studied in mice with one kidney exteriorized II The functional and the early post mortem morphology of the kidney Acta path microbiol scand 49 (1960) 297

HAUCH E Om nyrernes anatomi og deres udvikling (In Danish) Dissertation Copenhagen 1901

HEGEDUS V Three-dimensional estimation of renal shape and volume at angiography Acta radiol Diagnosis 12 (1972) 87

HODSON C J Physiological changes in size of the human kidney Clin Radiol 12 (1961) 91

— and CRAVEN J D The radiology of obstructive atrophy of the kidney Clin Radiol 17 (1966) 305

— and WILSON S Natural history of chronic pyelonephritic scarring Brit med J 2 (1965) 191

HOU JENSEN H Die Verastelung der Arteria renalis in der Niere des Menschen Z Anat Entwickl Gesch 1 (1930) 91

KARN M N Radiographic measurement of kidney section area Ann hum Genet 25 (1962) 379

DE LEON W GARCIA A and DE JESUS P J Normal weights of visceral organs in adult Filipinos Philipp J Sci 52 (1933) 406

LEYSSAC P P The regulation of proximal tubular reabsorption in the mammalian kidney Acta physiol scand (1966) Suppl No 291, p 62
LUDIN H Tomographische Bestimmung der Nierengrösse Fortschr Rontgenstr 95 (1961) 215
— Radiologic estimation of kidney weight Acta radiol Diagnosis 6 (1967), 561
MOELL H Kidney size and its deviation from normal in acute renal failure Acta radiol (1961) Suppl No 206
SCHREIBER M H Renal artery — parenchyma ratios in the diagnosis of renovascular hypertension Amer J Roentgenol 96 (1966) 877
SCHULTZ H U und ZIMMERMANN S Zur Nierengrösse im Rontgenbild Z Urol Nephrol 58 (1965), 757
WALD H The weight of normal adult human kidneys and its variability Arch Pathol 23 (1937) 493
WOJTOWICZ J Relationship of the surface parameters of the kidney to the size of the renal artery Invest Radiol 2 (1967) 231
VUORINEN P, ANTTILA P WEGELIUS U et coll Renal cortical index and other roentgenographic renal measurements Acta radiol (1962) Suppl No 211

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DIAGNOSIS OF TRICUSPID AND PULMONARY VALVE INSUFFICIENCY BY CINECARDIOANGIOGRAPHY

by

H G BOGREN D PICUKARIC and E CARLSSON

The cardioangiographic diagnosis of valvular incompetence depends on the demonstration of retrograde flow of contrast medium through the valve The function of the aortic and mitral valves may by demonstrated during the injection of contrast medium distal to the orifice of the pertinent valve without passing the catheter through its lumen valvular closure is thus unaffected The tricuspid and the pulmonary valves cannot be examined by the same means because the catheter must pass through them A rare exception is in the presence of a patent ductus arteriosus through which the tip of the catheter may be introduced into the main pulmonary artery With the catheter passing through the valve the question arises as to whether this per se produces insufficiency

This communication deals with the effect of such passage on the closure of the tricuspid and pulmonary valves when contrast medium is injected distal to them

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— Radiologic estimation of kidney weight Acta radiol Diagnosis 6 (1967) 561
MOELL H Kidney size and its deviation from normal in acute renal failure Acta radiol (1961) Suppl No 206
SCHREIBER M H Renal artery — parenchyma ratios in the diagnosis of renovascular hypertension Amer J Roentgenol 96 (1966) 877
SCHULTZ H U und ZIMMERMANN S Zur Nierengrosse im Rontgenbild Z Urol Nephrol 58 (1965) 757
WALD H The weight of normal adult human kidneys and its variability Arch Pathol 23 (1937) 493
WOJTOWICZ J Relationship of the surface parameters of the kidney to the size of the renal artery Invest Radiol 2 (1967) 231
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Fig. 1. Right cineventriculographies. a) Competent tricuspid valve. b) The contrast medium regurgitates from the right ventricle into the enlarged right atrium.

Results

Tricuspid valve. The function of the tricuspid valve after right ventricular injection of the contrast medium and its correlation to clinical and catheterization findings appear in Table 1.

The right ventricle was always filled during 3 to 4 beats. The valve was competent in every beat in 7 patients; one of these cases is illustrated in Fig. 1 a. The tricuspid valve in 6 patients was competent in normal beats but incompetent in extrasystolic beats; incompetence was evident in all extrasystolic beats in this group. A small extrasystolic beat in one patient in the first group, however, failed to produce incompetence. The valve in 3 patients was incompetent in one large postectopic beat during a short time in early systole, producing a small "puff" of contrast medium regurgitation. In another, such a beat produced incompetence in late diastole; the valve was competent during systole of the same postectopic beat. The tricuspid valve was incompetent in each beat in 5 patients, all with enlarged right atria (Fig. 1 b). The contrast medium regurgitated across the valve throughout systole, while in the irregular beats described the regurgitation lasted for only a fraction of systole. In 4 of the 5 patients with regurgitation in every beat, a characteristic systolic murmur of tricuspid insufficiency was present (high pitched and blowing and loudest at the lower aspect of the left sternal border). In the fifth instance no murmur at all was heard owing to a pericardial effusion; this patient had a patent ductus arteriosus and an atrial

Table I

Tricuspid valve function after right ventricular injection: correlation to clinical and catheterization findings

	No. of cases	Characteristic tricuspid insufficiency murmur	x wave in right atrium smaller than v wave
Competent in each beat	7	0	0
Competent in normal beats, incompetent in extrasystolic beats	6	0	0
Competent in normal beats, incompeteent in extrasystolic or one large postectopic beat	2	0	0
Incompetent in extrasystolic and one large postectopic beat	1	0	0
Competent in normal beats, incompetent in one large beat with overflow in diastole	1	0	0
Incompetent in each beat	5	4	0

Material and Methods. Twenty two randomly chosen angiographies of tricuspid valves and 22 of pulmonary valves were evaluated. The angiography had been performed in patients with and without clinical signs of valvular insufficiency. The function of the tricuspid valve was investigated in 7 females and 15 males, all except one were children aged between 5 days and 11 years, the adult patient was 47 years old. The pulmonary valve material also comprised 7 females and 15 males aged between 8 days and 65 years, of these 5 were adults and 17 were children.

The tip of the catheter was located above the pulmonary valve in the main pulmonary artery for the injection of contrast medium distal to it. The tip of the catheter was placed at the apex of the right ventricle for the examination of the tricuspid valve so that all the side holes lay in the ventricular cavity. The contrast medium (Renografin 76 %) was injected in amounts of about 1 ml per kg body weight, the injection rates varying from 2 to 20 ml per second, depending on the weight of the patient (2 to 65 kg). Biplane cineradiography was performed with 16 mm film at 60 exposures per second per plane and an exposure time of 4 ms. The exposures were alternated in the two planes at an average of 22 mA (peak 88 mA) and between 60 and 125 kV. Each frame of the cineradiographic record was searched for signs of normal and abnormal valve function. The results were correlated with those of the clinical examination and cardiac catheterization.



Fig 2 Cinefilms during injection of contrast medium into the main pulmonary artery Competent pulmonary valve

monary valve was competent in all beats in 12 instances and none regurgitated across it (Fig 2) Three pulmonary valves were competent in at least one beat but appeared incompetent in some beats when the catheter slipped into the right ventricular infundibulum (Fig 3) The catheter in 2 instances passed into the right ventricle during diastole in all beats observed In one instance one beat with a competent valve was evident in the following beat a small puff of contrast medium regurgitated across the valve during part of diastole The tip of the catheter which seemed to be caught lay in the uppermost part of the infundibulum and the pulmonary valve where its movement was restricted

Incompetence in all beats was evident in 4 patients (Fig 4) All the catheter side holes were situated in the main pulmonary artery and a characteristic murmur of pulmonary valve insufficiency (decrescendo murmur in early diastole) was associated with the incompetent valve In only one other patient was such



Fig 3 a) b) The contrast medium is injected into the main pulmonary artery c) Later in diastole The pulmonary artery has moved cranially and the contrast medium is also injected into the infundibulum through one of the side holes of the catheter

Table 2

Pulmonary valve function after pulmonary artery injection: correlation to clinical and catheterization findings

	No. of cases	Characteristic pulmonary insufficiency murmur	End diastolic pressure in pulmonary artery equal to that in right ventricle
Competent in each beat	12	0	0
Competent in at least one beat, incompetent after catheter slipped into right ventricle	3	0	0
Incompetent in all beats, catheter slipped into right ventricle	2	0	0
Competent in one beat, slightly incompetent in one beat with the catheter caught	1	0	0
Incompetent in all beats with all catheter side holes in pulmonary artery	4	4	0

septal defect as well, neither of which produced any audible murmurs. The typical murmur in tricuspid insufficiency usually cannot be differentiated from that of a ventricular septal defect, absent in the 4 patients mentioned. Such a septal defect was present in 2 patients in whom the tricuspid valve was competent in normal beats as well as in the patient with incompetence in extrasystolic beats and in one large postectopic beat. These patients had murmurs that could not be differentiated from one of tricuspid insufficiency. They were considered as probably caused by the ventricular septal defects and are therefore described in Table 1 as without characteristic tricuspid insufficiency. The diagnosis of tricuspid insufficiency is considered if at the catheterization the a wave in the right atrium is significantly smaller than the v wave. None of the patients of the present series presented this sign. One of the patients with clinical and cardioangiographic evidence of tricuspid insufficiency was operated upon and the diagnosis was confirmed as a defect in the septal leaflet (Fig. 1 b).

Pulmonary valves. Pulmonary valve function following injection of contrast medium into the pulmonary artery and its correlation to clinical and catheterization data are presented in Table 2.

The main pulmonary artery in all 22 angiographies in this series was filled with contrast medium during 2 to 4 heart beats, generally 3 to 4 beats. The pul



Fig 4 Injection of contrast medium into the main pulmonary artery Some regurgitation across the incompetent pulmonary valve

short time in early systole expect in one instance when this occurred in late diastole A possible explanation is that the closure of the tricuspid valve depends on a correct sequence of atrial and ventricular contractions (RUTISHAUSER et coll 1966) Incompetence would then result if this sequence were disturbed, as during the long diastole of large postectopic beats (GRANT et coll 1963) The valve may be closed during a part of diastole and open again before the delayed ventricular contraction starts This closure and opening would explain the regurgitation in early systole as well as in late diastole

A not uncommon phenomenon observed earlier although not in any of the patients in this series was that the catheter moved during the injection so that one or more side holes lay in the right atrium The function of the valve cannot then of course be determined The siting of the tip of the injection catheter at the apex of the right ventricle to avoid such movements is important

Atrial pressure indicating a v wave larger than the a wave is considered a sign of tricuspid valve insufficiency This abnormality in the waves was not evident in this series

The murmur in tricuspid incompetence is characteristic but without angiography cannot be differentiated from that associated with a ventricular septal defect

Pulmonary valves It is commonly stated that the function of the valve cannot be evaluated with a catheter in a valve ostium It was therefore somewhat surprising that more than half of the patients in this series had competent valves in each beat The location of the catheter within the valve ostium does not seem to influence valvular function unless the catheter becomes caught inadvertently since this was observed only once it is unusual Furthermore the catheter was

a murmur heard, one with aortic insufficiency and a pulmonary valve that was competent in all beats Since the murmurs of aortic and pulmonary insufficiency are alike, the murmur in this patient was attributed to the former

The observation on catheterization of an end diastolic pressure of the main pulmonary artery equal to that in the right ventricle is considered an indication of pulmonary valve insufficiency, this was not evident in the series

Discussion

Tricuspid valve It would appear that the 5 instances of regurgitation through out *systole in each beat represents true tricuspid insufficiency The diagnosis* was confirmed at operation in one patient, and in 4 patients characteristic tricuspid insufficiency murmurs were present The absence of murmurs in the fifth patient was possibly due to pericardial effusion causing cardiac tamponade Con sequently, the criterion for the angiographic diagnosis of tricuspid incompetence is evidence of regurgitation across the valve throughout systole in each beat Such consistent regurgitation was not evident in any of the remaining 17 patients who were without clinical signs of tricuspid incompetence In 16 of these at least one normal beat during which the valve was competent was recorded, no leaking normal beat was noted In the seventeenth patient, the beats were only extrasystolic or postectopic and regurgitation was observed during a part of systole The regurgitation lasted only during part of systole in all patients with extrasystolic beats and postectopic beats, only a small puff of contrast medium was usually visible If regurgitation ended before systolic contraction was com pleted, the valve was considered competent

The complete competence of the tricuspid valve when beats are normal in dicates that closure of the valve is completed before systole begins *Closure of* the tricuspid valve might be assumed to be caused by movement of the blood, instigated by contraction of the ventricle, so that a small amount of contrast medium would then be expected to regurgitate into *the right atrium in each beat* Such regurgitation takes place during extrasystoles a puff of contrast medium *enters the right atrium before the tricuspid valve closes* and the valve is then *competent during the rest of systole The tricuspid* valve seems to require un interrupted diastole for its normal closure

This conception of the closing mechanism of the tricuspid valve is supported by experimental work in dogs TEI NES (1971) placed tantalum markers in the tricuspid valve and timed its closure in relation to the start of the right ventric ular contraction He demonstrated that the tricuspid valvular leaflets move into a closed position before the contraction of the anterior wall of the right ventricle begins

The contrast medium in all the large postectopic beats regurgitated for a

The competence of the pulmonary and tricuspid valves may be easily evaluated by cinecardioangiography. Its superiority over the conventional slow exposure rate method in this evaluation is obvious: it allows analysis of small parts of the cardiac cycle and therefore produces a more precise diagnosis.

Acknowledgements

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SUMMARY

The effect of cardiac catheters in the ostia of the tricuspid and pulmonary valves during cinecardioangiography was examined in 44 patients. Valvular function appeared not to be affected in normal beats. The competence of the valves was easily evaluated by the angiography. The findings are correlated to clinical and catheterization data.

ZUSAMMENFASSUNG

Die Einwirkung der Herzkatheter auf die Ostien der Tricuspidal- und der Pulmonalklappen während der Cinekardioangiographie wurde bei 44 Patienten untersucht. Bei normalen Schlägen scheint die Klappenfunktion nicht beeinträchtigt zu werden. Die Funktionsfähigkeit der Klappen war durch die Angiographie leicht festzustellen. Die Ergebnisse werden zu den klinischen und Katheterisierungsbefunden korreliert.

RÉSUMÉ

Les auteurs ont étudié sur 44 malades l'effet des cathéters cardiaques dans l'ostium des valvules tricuspides et pulmonaires pendant la cinécardioangiographie. La fonction valvulaire ne paraît pas être affectée dans les contractions normales. L'angiographie permet d'évaluer aisément le fonctionnement des valvules. Les résultats de cet examen sont confrontés aux données de la clinique et du cathétérisme.

REFERENCES

GRANT C, GREENE D and BUNNELL I: The valve closing function of the right atrium. Amer J Med 34 (1963) 325.

KJELLBERG S R, MANNHEIMER E, RUDHE U and JONSSON B: Diagnosis of congenital heart disease. Year Book Medical Publishers, Chicago 1955.

RUTISHAUSER W, WIRZ P, GANDER M and LÜTHY E: Atriogenic diastolic reflux in patients with atrioventricular block. Circulation 34 (1966) 807.

TERNES R: Tricuspid valve closure in intact unanesthetized dogs. Master's dissertation, San Diego State University, San Diego, California 1971.

impeded only during the second beat and no regurgitation of contrast medium apparently occurred during the first beat

The right ventricular infundibulum and the main pulmonary artery, including the valve, move extensively during a cardiac cycle, cranially and dorsally during diastole, caudally and ventrally during systole (KJELLBERG et coll 1955) A catheter placed in the main pulmonary artery through the valve ostium often follows the cardiac structures in which it is situated so that the tip of the catheter and its side holes remain in the main pulmonary artery during the entire cardiac cycle In 5 instances in the series, however, at least one of the side holes was situated in the infundibulum during its upward and posterior movement in diastole, resulting in injection of contrast medium below the area of the pulmonary valve (Fig 3) This slipping of the catheter seems to be the main problem in the evaluation of function of the pulmonary valve Its avoidance is difficult as it may happen even if the tip of the catheter be placed 2 to 3 cm above the valve, it sometimes failed to occur when the tip of the catheter and its holes were sited just above the valve If it takes place in all beats, as in 2 of the patients, the function of the valve cannot be evaluated cardioangiographically

Correlation between the clinical finding of a characteristic pulmonary insufficiency murmur and pulmonary valve insufficiency was high Aortic and pulmonary insufficiency in the same patient makes evaluation of the murmur difficult The diagnostic criteria for differentiating pulmonary insufficiency from pressure measurements are uncertain and seem to be much less accurate than those by cardioangiography

Conclusions

The presence of cardiac catheters in the ostia of the tricuspid and the pulmonary valves appeared not to affect valvular function in normal beats

The regurgitation during injection of contrast medium into the main pulmonary artery in patients without organic incompetence of the valve is usually produced by the movement of the right ventricular outflow tract cranially in diastole The side holes of the catheter will then be situated proximal to the valve The contrast medium is actually injected into the infundibulum of the right ventricle during late diastole when the craniodorsal movement of the infundibulum is at its maximum The tricuspid valve is generally incompetent during extrasystolic and large postectopic beats This is in agreement with what is known about the closure mechanism of the tricuspid valve which seems to require a correct sequence of atrial and ventricular contraction to shut normally When true insufficiency of the tricuspid valve is present, regurgitation of contrast medium takes place throughout systole Regurgitation during *only* a part of systole has no pathologic significance

more than an auxiliary tool to assist in the clarification of practical problems in the radiographic examination technique. It was used to ascertain the conditions to be chosen in the various examination modalities to ensure optimum image quality with the commercially available generators, roentgen tubes, examination units and image recording facilities.

The modulation transfer function is known to be only one of the parameters determining image quality; the various sources of noise are also of considerable influence. Experience has indicated that an optimum radiographic technique may be obtained by a simplified assessment of the image quality based on the modulation transfer function of the image transfer system.

With the great number of parameters involved the entire course of the modulation transfer function for all spatial frequencies ν, extending as far as the cut off frequency, was not considered; attention was paid only to a few fixed spatial frequencies known to be of importance in diagnostic objectives and the pertinent contrast transfer factors were calculated.

The mathematical approach to the problem was as follows:

Image contrast $C_i = f$ (focal spot size, FFD, FOD, object velocity v, characteristics of film screen system) to be made maxim.

Exposure time $t = f$ (focal spot size, generator kV, mAs) to be made minim.

$C_i(\nu)$ = radiation contrast C_s $\times$ contrast transfer factor $C(\nu)$

As the functions for the image contrast C_i and the minimum exposure time t_m are not given in a simple analytical form, the parameters mentioned were varied until maximum image contrast, i.e. the maximum contrast transfer factor, $C(\nu)$ was attained.

The $C(\nu)$ values were computed with the help of the Siemens data processing system 4004 as product of the contrast transfer factors for the radiation geometry $C_g(\nu)$, the object movement $C_m(\nu)$ and the film screen system $C_f(\nu)$ while the parameters were varied within the limits of practical interest. The contrast transfer factors of the radiation geometry $C_g(\nu)$, and the object movement $C_m(\nu)$ are according to MORGAN (1962) determined by the formulae

$C(\nu) = C_g(\nu) \times C_m(\nu) \times C_f(\nu)$

$C(\nu)$ contrast transfer factor for spatial frequency ν

$C_g(\nu)$ contrast transfer factor due to geometry

$$C_g(\nu) = \frac{\sin \frac{\pi \nu}{\nu_c}}{\frac{\pi \nu}{\nu_c}} \quad \text{cut off frequency } \nu_c = \frac{M}{F(M-1)}$$

M magnification, F focal spot size

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COMPUTER-AIDED OPTIMIZATION OF RADIOGRAPHIC CONDITIONS

by

H. GAJEWSKI and H. KUHN

Sharpness, an important factor in roentgenographic quality, depends on *numerous interdependent factors: loading capacity, focus film distance*, focal spot size, movement of the object, speed of film screen system, voltage wave form and output of the generator all influencing the exposure time, the most essential factor in the examination of the human subject.

The most important conditions to be taken into account if optimum detail is to be obtained are: The geometry or the focal spot size and the magnification (FFD/FOD), the movement or object velocity and exposure time, and the speed, contrast and definition of the film screen system. Since these may *produce compensatory effects, endeavours must be aimed at arriving at the* most favourable compromise between the various parameters so as to ensure optimum image quality. The concept of modulation transfer function was found to be more suitable and informative for this than the condition of equivalence in the components of unsharpness used earlier.

The investigations were consequently not concerned with the properties of the modulation transfer function and how to measure it. The function was no

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Based on a paper given at the XII International Congress of Radiology, Tokyo, October 1969. Submitted for publication 23 July 1971.

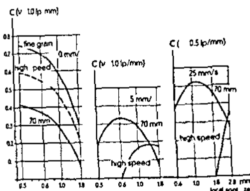


Fig 2 Low potential (65 kV) Full size roentgenography and 70 mm fluorography of the oesophagus (stout patient) Contrast transfer factors for various speeds of movement as a function of the focal spot size Twelve pulse generator FFD 70 cm

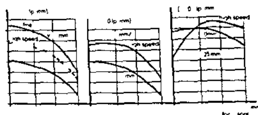


Fig 3 High potential (125 kV) Full size roentgenography and 70 mm fluorography of the oesophagus (stout patient) Contrast transfer factors for various speeds of movement as a function of the focal spot size Twelve pulse generator FFD 70 cm

figures of 80 cm and more used in practice with a 160 kW tube having a focal spot of 1 8 mm at a target angle of 12°

The same method of calculation may of course also be applied to all other image recording procedures Some results of such calculations for the comparison of full size roentgenograms and almost quantum noise free 70 mm intensifier fluorograms of the oesophagus under extreme conditions (stout patient low kV) with the parameters of the object speed v and the focus size appear in Fig 2

As is to be expected the contrast transfer obtained with full size roentgenograms of motionless objects ($v = 0$) is definitely superior to that obtained with a 70 mm film particularly when a small focal spot and high definition screens are used

A 70 mm film is superior to a screen film even at a low object speed ($v = 5$ mm/s) as smaller focal spots may be used due to a greatly reduced exposure time The optimum focal spot size would be 0 6 mm

The curves on the right side (Fig 2) indicate (for a spatial frequency of 0 5 lp/mm) that with higher object speed ($v = 25$ mm/s) the contrast transfer factor of the 70 mm film is much higher with an optimum focal spot size of 1 mm than in full size roentgenography this obtains even when a 2 8 mm focus of very high rating is employed in full size roentgenography

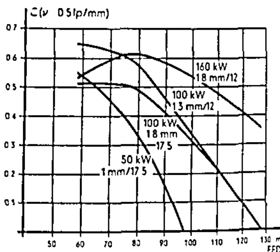


Fig. 1. Image quality in coronary angiography. Contrast transfer factors at 0.5 lp/mm as a function of the FFD for various tube types. Twelve pulse generator, normal patient, 75 kV, Siemens Special screen, object velocity 200 mm/s, FOD 25 cm

$C_v(\nu)$ contrast transfer factor due to movement

$$C_v(\nu) = \frac{\sin \frac{\pi \nu}{\nu_c}}{\frac{\pi \nu}{\nu_c}} \quad \text{cut off frequency } \nu_c = \frac{1}{v \cdot t}$$

v object velocity, t exposure time

$C_f(\nu)$ contrast transfer factor of film screen system (taken from measurements)

The cut off frequencies ν_c are dependent on the magnification scale, the focus size, the object velocity as well as on the exposure time, respectively. The contrast transfer factors $C_f(\nu)$, of the roentgen film intensifying screen systems were taken from the modulation transfer functions measured.

The results of such a computation are demonstrated in an example of coronary angiography with the AOT film changer. Fig. 1 indicates the contrast transfer factor for the spatial frequency 0.5 lp/mm in the object plane as a function of the FFD for four different tube types for the conditions mentioned. The following conclusions may be drawn from the curve shape. (1) The contrast transfer factor decreases with the FFD, regardless of the tube type. This is caused by the kinetic blurring increasing with the exposure time which, in turn, rises with the square of the FFD. The FFD in coronary angiography should therefore be reduced as much as the unit dimensions permit. The use of high speed screens is indicated for the same reason. (2) Higher contrast transfer factors are attained with the 100 kW tube in spite of the larger focal spot. (3) A further improvement in image quality would be obtained at the FFD

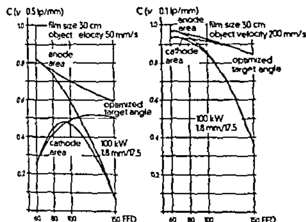


Fig 5 Optimum target angle Contrast transfer factors as a function of the FFD left for 50 mm/s speed of movement and $r = 0.5$ lp/mm and right for 200 mm/s and $r = 0.1$ lp/mm Each FFD in the curve optimized target angle is assigned a target angle that permits a collimated field size of 30 cm × 30 cm The focal spot is 1 8 mm in all cases although the associated tube loadings vary with the target angle for FFD 150 cm the optimum target angle is 7.5 and the tube loading 230 kW The appropriate values for a FFD of 60 cm are 21 and 85 kW At an FFD of ?? cm the optimum target angle is equal to the target angle of 17 5 of the commercially available 100 kW tube (corresponding to the point of intersection of the appropriate curves)

0 /9 A detail about 1 mm in diameter with low radiation contrast that can easily be recognized at the anode side might, under certain circumstances not be evident on the cathode side of the roentgenogram The conventional tube with a target angle of 17 5° demands an FFD of 95 cm, at which the contrast transfer factor at the cathode image margin has its maximum value The curves labelled optimized target angle supply the answer to the question as to whether such a thing as an optimum target angle exists The target angle is a factor upon which depends the focal size and thus the tube rating the size of the collimated field at a given FFD and the difference of the optical focal size in various radiation beam directions A comparison of the curves for an optimally elected target angle with the curves for a commercial tube indicates that with a small FFD no quality improvement can be achieved by suitable selection of the target angle but at 1 m or more an optimum of the target angle may be worthwhile This is particularly clear in chest roentgenography to which the right hand diagram refers.

The spatial frequency 0 1 lp/mm associated with the diagram is admittedly too small for the detail obtaining in chest roentgenograms but comparison between the left and right diagrams of Fig 5 is intended to demonstrate that even for higher spatial frequencies and lower object speeds at the FFD of 150 cm usual for chest roentgenography higher contrast transfer factors are always obtained with the optimum target angle than with the normal one of 17 5 The diagnostically important spatial frequencies between 0 1 and 0 5 lp/mm may under certain conditions thus be represented in chest films with

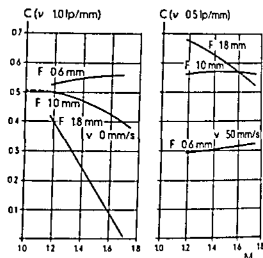


Fig. 4. Variation in magnification. Contrast transfer factors as a function of the scale of magnification for various focal spot sizes and speeds of movement (left: $v = 0$ mm/s and $\nu = 1.0$ lp/mm; right: $v = 50$ mm/s and $\nu = 0.5$ lp/mm). Siemens Special screens. FFD 70 cm.

The results with the high kV technique are considerably different (Fig. 3). Since the exposure time, and thus the kinetic blurring, may be considerably reduced at high potential, equally good or even better contrast transfer factors are obtained even with full size roentgenograms, compared with intensifier fluorograms. These results agree satisfactorily with practical experience (for example of KAUDE 1967).

These considerations with respect to optimum image quality are subject to certain limitations. The detail of a spatially extended object is represented at a varying magnification (Fig. 4). Furthermore, the optically effective focal spot changes its size with the beam direction and not all parts of the object move at the same speed. The object film distance, i.e. the magnification scale, has practically no bearing on the contrast transfer factor with a suitable choice of the focal size, in other words, a good depth of definition is obtained with a spot filming device. A comparison of the left and right curves ($v = 0$ and 50 mm/s) reveal on the other hand, that different object speeds result in different optimum focal spot sizes (0.6 and 1 mm). This result emphasizes the need for the use of double focus tubes.

The variation in the optically effective focal spot size over the image field, in particular in the direction of the longitudinal axis of the roentgen tube, results in differences in the contrast transfer factors between the image margin at the anode side and that at the cathode side.

The results calculated for a selected case are presented in Fig. 5. The contrast transfer factors at the two film margins are plotted as a function of the FFD for a film size of 30 cm × 30 cm (curves: 100 kW/1.8 mm/17.5°) on the left hand side. The image quality at these two points differs considerably with a small FFD, at 70 cm the contrast transfer factors are, for example 0.36 and

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TUMOURS OF THE QUADRIGEMINAL PLATE AND ADJACENT STRUCTURES

by

TORGNY GREITZ

Tumours of the quadrigeminal plate are of special diagnostic interest because of the difficulty in their differentiation from those arising in adjacent structures particularly the pineal gland and the posterior part of the thalamus This is easily understood from the close relationship that exists between these bodies Because tumours of the pineal body such as gliomas may infiltrate the quadrigeminal plate and growths of the latter involve the pineal body, it may be impossible even at necropsy to determine their primary site This has meant that all tumours in this area have simply been called tumours of the pineal region and under this heading fifty or more different histopathologic types have been described LOFGREN in his classical paper on the angiographic diagnosis of tumours in the pineal region concluded "vertebral angiography and pneumography together permit a precise determination of the essential features of the tumour LOFGREN however distinguished only between neoplasms of the thalamus and those of the pineal region and made no attempt to differentiate pinealomas from tumours of the quadrigeminal plate and the upper brain stem

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a tube having an optimal target angle while if a tube such as is normally commercially available be used they would remain under the threshold of resolution Calculation gave a target angle of 7 5° for a focal spot of 1 8 mm and a tube loading of 230 kW The gain in contrast with a tube with an optimum target angle for a special chest set up with a FFD of 150 cm, is considerable

Finally, it should be noted that the experimental verification of the calculations carried out by spot checks with the aid of views of grids yielded a satisfactory result The aim of the investigations was to confirm the opinion that the *concept of the modulation transfer function is a useful tool in creating* optimum roentgenographic conditions

SUMMARY

The factors influencing the quality of the image were obtained under the concept of the modulation transfer function by determining the maxima of the contrast transfer factors for spatial frequencies (detail sizes) with a computer A comparison of 70 mm image intensifier fluorography and full size radiography is made and geometric magnification and the optimum target angle of the roentgen tube are discussed

ZUSAMMENFASSUNG

Die Faktoren die die Bildqualität beeinflussen wurden mit Hilfe des Konzepts der Modulationsübertragungsfunktion durch Bestimmung der Maxima der Kontrastübertragungsfaktoren für bestimmte Ortsfrequenzen (Detailgrossen) mit einem Computer ermittelt Ein Vergleich der 70 mm Bildverstärkerphotographie mit der Direktaufnahme wird angestellt und die geometrische Vergrösserung sowie der optimale Anodenwinkel der *Röntgenröhre* diskutiert

RÉSUMÉ

Les facteurs qui influent sur la qualité de l'image ont été étudiés du point de vue de la fonction de transfert de modulation en déterminant les maxima de facteurs de transfert de contraste pour des fréquences spatiales (dimensions de détails) au moyen *d'un ordinateur* Les auteurs font une comparaison entre l'ampliphotographie en 70 mm et la radiographie en vraie grandeur et ils étudient l'agrandissement géométrique et l'angle optimal de l'anticathode du tube radiogène

REFERENCES

Kaude J Fluorography of the gastroduodenal tract A comparative study with *70 mm film* Acta radiol Diagnosis 6 (1967) 353

Morgan R H The frequency response function Amer J Roentgenol 88 (1962) 175



Fig 1



Fig 2

Fig 1 Autopsy material Small glioma (astrocytoma) in the mesencephalon (→) causing obstruction of the aqueduct and moderate hydrocephalus The quadrigeminal cistern is essentially normal and bordered antero-inferiorly by the colliculate plate anteriorly by the third ventricle superiorly by the splenium and postero-inferiorly by the vermis of the cerebellum The antero-superior and postero-superior surfaces of the cerebellum form an angle of about 90 degrees and have a smoothly rounded contour (↔)

Fig 2 Malignant glioma of the mesencephalon invading the thalamus The colliculate plate and the mesencephalon are pushed postero-inferiorly indenting the anterior part of the floor of the fourth ventricle (→) which has a raised appearance The curve of the anterior medullary velum is increased The angle between the velum and the nodulus is decreased to give a pointed appearance to the fastigium There is a deformity of the upper part of the vermis the surface of which is concave antero-superiorly (↔)



Fig 3



Fig 4

Fig 3 Huge glioma extending superiorly into the lateral ventricles and elevating and compressing the corpus callosum from below The tumour fills most of the fourth ventricle Marked deformity of the vermis (→) the upper part of which is pointed instead of normally rounded

Fig 4 Astrocytoma of the upper brain stem filling the quadrigeminal cistern and diffusely infiltrating the superior vermis The fourth ventricle is raised (→) and the fastigium compressed (↔)

LÖFGREN's important work has been followed by contributions on the normal anatomy of the arteries and veins in this area (GALLOWAY et coll 1960, GREITZ et coll 1963, MANI et coll 1968, WESTBERG 1963, 1969, WOLF et coll 1963, HUANG et coll 1965, 1966). These have prompted a review of the radiologic features of growths in this area with special emphasis on the differential diagnosis; this has been based on observations made in an autopsy material and on information gained from clinical encephalography and angiography.

Material and Methods

Autopsy material. Thirty one brains with histologically verified tumours in the pineal region were investigated. The neoplasms consisted of 11 gliomas, 17 pinealomas, 1 neuroblastoma, 1 teratoma and 1 papilloma. The brains were fixed in formalin, being allowed to float freely during fixation so as to prevent distortion; they were photographed during dissection.

Clinical material examined by encephalography or ventriculography. Films were available for 27 cases that had been investigated by pneumography and had histologically verified tumours in the pineal region. Of these, 9 were gliomas, out of which 1 arose from the quadrigeminal plate, 1 from the mesencephalon and thalamus, 2 from the mesencephalon and 1 only from the posterior thalamus, while in 4 cases the origin was difficult to define; of these 4 cases 1 was an ependymoma, 1 a papilloma and 2 teratomas. Two of the gliomas were ependymomas, 1 a glioblastoma and the remaining tumours were of varying grades of malignancy (astrocytoma, spongioblastoma, polymorphic glioma and gliomatous tumour). Eighteen growths were pinealomas (3 iso-morphic and 10 two cell pinealomas; of these 2 were malignant with metastases, 2 were pineoblastomas, 1 a pinealoma of the 'germinoma type' and 1 a pinealoma of the adenomatous type). The diagnosis in one pinealoma was made by needle biopsy. Ventriculography was performed in 14 of these 27 cases, encephalography alone in 12 cases and combined with ventriculography in 1 case.

Clinical material examined by angiography. Vertebral angiography was carried out in 13 of the cases examined by pneumography. Seven of these were gliomas, 2 of which were entirely or partly growing in the thalamus and 6 were pinealomas. Unilateral or bilateral carotid angiography was carried out in addition in 3 of these tumours. Two growths, 1 ependymoma and 1 teratoma, were examined by carotid angiography only. Included in the material were 1 meningioma of the tentorium and 2 arachnoid cysts, all investigated by vertebral angiography. The angiographic changes in these lesions were compared with those in 3 cases of aqueduct stenosis.

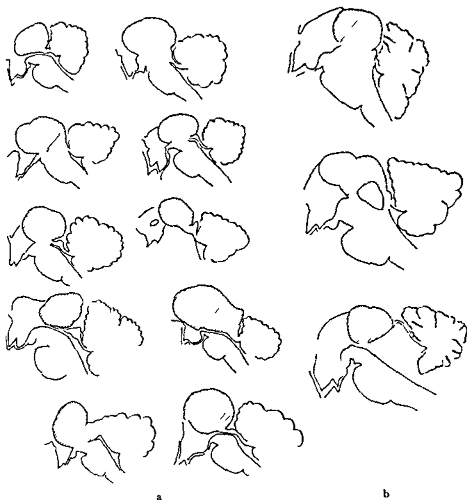


Fig 7 Autopsy material a) Ten cases of pinealomas with no obvious deformity of the vermis in 7 and diffuse infiltration in 1 case Kinking of the aqueduct and humping up of the posterior colliculate body evident in serveral cases b) Three pinealomas deforming the vermis one with diffuse infiltration of the brain stem another with haemorrhage in the mesencephalon and a third with marked hydrocephalus of the fourth ventricle

Tumours others than pinealomas usually produced indentation of the anterior part of the vermus which was sometimes markedly compressed to give it a pointed instead of the normal more rounded appearance (Figs 2, 3 6) The upper and posterior surfaces normally form an angle of slightly under 90 degrees (Fig 1) Only in 4 out of the 14 tumours other than pinealomas was there no deformity of the vermis One of these was an ependymoma (Fig 6) 3



Fig. 5. Pinealoma elevating the splenium of the corpus callosum and causing slight inferior displacement of the vermis; no deformation of the folia vermis. The tumour causes compression of the aqueduct and of the anterior colliculate bodies which are atrophied. The posterior colliculate bodies are displaced postero-inferiorly and deformed by compression from the antero-superior aspect giving them the appearance of a hump. Kink of the aqueduct evident at the same level.

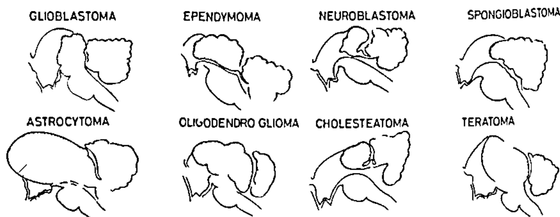


Fig. 6. Autopsy material. Dissected specimens. Extension of 8 tumours other than pinealomas and the deformities produced. No deformity of the vermis in the glioblastoma and the ependymoma. *The remainder: Indentation in the anterior surface* in 5 and infiltration in 1.

Results

Pathology. The quadrigeminal plate lies next to the quadrigeminal cistern, which is bordered antero-superiorly by the posterior part of the third ventricle and the pineal body, superiorly by the splenium of the corpus callosum and postero-inferiorly by the vermis of the cerebellum (Fig. 1). Neoplasms of the vermis do not offer any problems in the differential diagnosis and will therefore not be considered. It seemed logical to assume that involvement of the quadrigeminal plate would be more likely to cause compression and obstruction of the aqueduct and to impinge upon the vermis than tumours from the pineal region; the latter would be more liable to affect the posterior part of the third ventricle and the thalami.

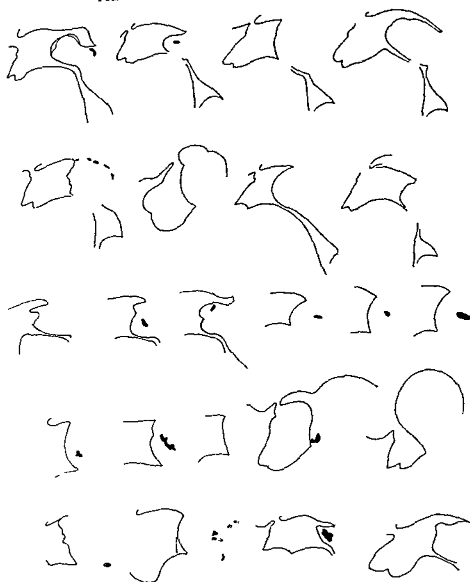


Fig 9 Clinical material a) The two upper rows Deformities of the ventricular system at pneumography in 8 gliomas The dots posterior to the third ventricle in 3 cases denote calcification b) The three lower rows Deformities of the posterior part of the third ventricle in 15 cases of pinealoma and position of calcification



Fig 8 Autopsy material Two cases of ectopic pinealoma raising the fourth ventricle and deforming the vermis

were small tumours, 2 of which were astrocytomas (Fig 1) and one was a glioblastoma (Fig 6) Two of these small gliomas were confined to the mesencephalon, all the other gliomas were invading the thalamus and were then usually assymmetric When the gliomas were growing superiorly they usually caused elevation of the splenium (Figs 3, 4) Two of the gliomas extended diffusely into the vermis (Figs 4, 6) so that its deformity was less obvious

The pinealomas were usually associated with depression and atrophy of the anterior colliculate body with posterior displacement and humping up of the posterior colliculate body, which appeared to be thickened (Fig 5) Along with these changes, depression and a characteristic kink of the aqueduct at the level of the posterior colliculate body were evident (Figs 5, 7) The fourth ventricle sometimes presented a raised appearance, similar to that evident in an axial pressure cone (LINDQUIST 1961), obviously due to the postero inferior displacement of the mesencephalon in relation to the pons The deformity of the colliculate plate and the characteristic kink of the aqueduct was observed in all specimens of pinealoma, in which these structures could be evaluated Most pinealomas were associated with elevation of the splenium, even in small tumours causing no deformity of the vermis (Fig 5) As opposed to the findings in gliomas, the deformity of the vermis was less frequent in pinealomas, i e only in 5 out of 18 specimens (Figs 7 8) These 5 cases included 2 of ectopic pinealoma (Fig 8) that might have contributed to the deformity, one of the remaining 3 cases with this deformity of the vermis (Fig 7 b), had diffuse infiltration of the brain stem, one an haemorrhage in the region of the aqueduct and the third had marked dilatation of the fourth ventricle

Pneumography The 9 cases of gliomas examined by pneumography included 4 with lateral displacement of the posterior part of the third ventricle (Fig 3) The indentation in the posterior part of the third ventricle was definitely irregular in one case of polymorphic glioma, in 5 cases it was polycyclic (Fig 9 a) The shape of the aqueduct could be ascertained in 5 cases and in 4 the typical kinking in tumours of this region was evident One papilloma had an irregular indentation while 2 teratomas produced an indentation from behind and below, one with rounded, and the other with polycyclic appearances (Fig 10) Out of the

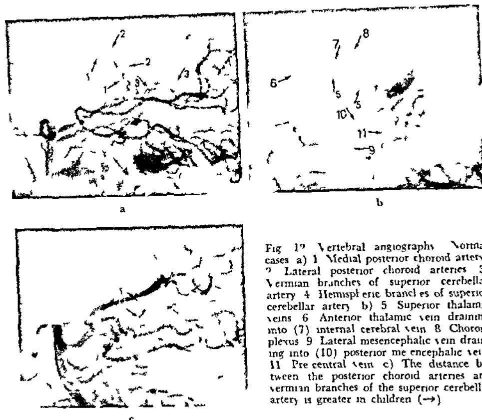


Fig 17 Vertebral angiography Normal cases a) 1 Medial posterior choroid artery 2 Lateral posterior choroid arteries 3 Vermian branches of superior cerebellar artery 4 Hemispheric branches of superior cerebellar artery b) 5 Superior thalamic veins 6 Anterior thalamic vein draining into (7) internal cerebral vein 8 Choroid plexus 9 Lateral mesencephalic vein draining into (10) posterior mesencephalic vein 11 Pre central vein c) The distance between the posterior choroid arteries and vermian branches of the superior cerebellar artery is greater in children (→)

is connected anteriorly with the cisterna veli interpositi posteriorly with the subarachnoid space over the vermis and inferolaterally with the ambient cistern with a lateral extension the choroid fissure behind the thalamus (Fig 14 a)

Encephalography in all but one of the 6 pinealomas revealed compression of the anterior part of the aqueduct and the typical kink at the level of the posterior colliculate body The quadrigeminal plate was displaced inferiorly (Figs 14 b 16 a) The choroid fissure was filled in 4 and dilated in 2 cases The upper part of the vermis could always be evaluated and was displaced inferiorly with the quadrigeminal plate it was deformed with a slightly concave anterior border only in two cases No asymmetry of the brain stem was evident Five of the 6 gliomas in which the configuration of the upper vermis could be ascertained at encephalography had deformity with a concave anterior surface and backward displacement of the vermis (Figs 18 20) The anterior part of the aqueduct was depressed and kinked (Fig 20) in all but 2 cases both of



Fig 10 Clinical material Deformities and calcification in 2 teratomas (left) and 1 papilloma (right)



Fig 11 a) *Arteries and veins in the pineal region adjacent to the mid sagittal plane and filled at angiography of the vertebral artery* 1 Posterior pericallosal artery 2 Medial (posterior) *choroid* artery 3 Vermis branches of superior cerebellar artery 4 Great vein of Galen 5 *Superior* vermian veins 6 Pre central vein b) Vessels located laterally in the vicinity of the *tentorial notch* 1 Posterior cerebral artery 2 Lateral (posterior) choroid artery 3 Hemispheric branches of superior cerebellar artery 4 Superior thalamic vein 5 Anterior thalamic *vein draining* into (6) internal cerebral vein 7 Basilar vein 8 Lateral mesencephalic vein *draining into* (9) posterior mesencephalic vein

17 pinealomas only one (of the germinoma type) displaced the third ventricle laterally The main part of this tumour lay in the right thalamus and the features at encephalography were those of a posterior thalamic tumour A pinealoma bulging up into the lateral ventricles was always strictly mid line and well demarcated from the thalamus on both sides (Fig 15) The indentation *in the posterior* part of the third ventricle was irregular only in one case, a pineoblastoma, and polycyclic in 6 cases (Fig 9 b) Polycyclic appearances were evident in 5 cases of small tumours, 3 of which had intact pineal recesses and in 2 cases of small malignant pinealomas with metastases, one with an ectopic pinealoma

The subarachnoid spaces, which are primarily affected by tumours in the pineal region, are well outlined by encephalography The quadrigeminal cistern

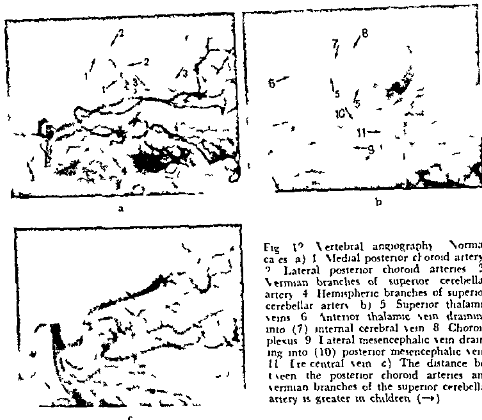


Fig 12 Vertebral angiography Normal cases a) 1 Medial posterior choroid artery 2 Lateral posterior choroid arteries 3 Vermian branches of superior cerebellar artery 4 Hemispheric branches of superior cerebellar artery b) 5 Superior thalamic veins 6 Anterior thalamic vein draining into (7) internal cerebral vein 8 Choroid plexus 9 Lateral mesencephalic vein draining into (10) posterior mesencephalic vein 11 Precentral vein c) The distance between the posterior choroid arteries and vermian branches of the superior cerebellar artery is greater in children (→)

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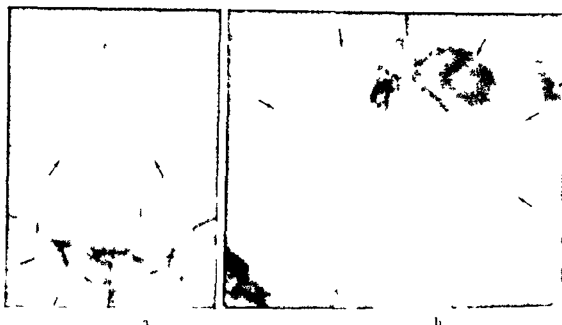


Fig 13 a) The thalamic veins filled in the early venous phase or as early as the capillary phase Arrows point to the anterior laterally directed limbs of the superior thalamic veins b) The thalami are richly suffused with contrast medium in the capillary phase

tumours of the thalamus (Fig 22) The choroid fissure was filled in 4 cases and dilated at least on one side (Fig 20) Asymmetry of the brain stem (Fig 18) was noted in all but 2 gliomas (Fig 20), in the 2 thalamic tumours however this was at least partly due to concomitant herniation A raised appearance of the fourth ventricle, not evident in the cases of pinealomas, was noted in 1 glioma Inferior displacement of the fourth ventricle with decreased distance between the fastigium and the postero-superior recesses was observed in 3 large gliomas but was not present in the cases of pinealomas (Fig 20)

The boundaries of most masses in the quadrigeminal region may be ascertained at encephalography The posterior aspect of the third ventricle defines the anterior and sometimes the upper border of the tumour as well The posterior border may be outlined against the air in front of the cerebellum The a p projection frequently also includes information as to the lateral borders (Figs 18, 20) The inferior border of the tumour is more difficult to ascertain, the a p projection, however sometimes affords an indication of the lower border when the lesion reaches laterally beyond the brain stem (Fig 20 b)

A lesion of differential diagnostic interest is the subarachnoid cyst Two such cases in this material caused antero superior displacement of the posterior part of the third ventricle and inferior displacement of the vermis, resulting in an

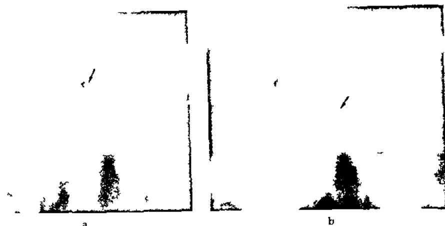


Fig 14 Encephalography a) Normal mid line tomogram The quadrigeminal cistern and its boundaries including the superior vermis and the colliculate plate with the posterior colliculate bodies indicated (→) b) Small pinealoma with calcification in the lower part of tumour The colliculate plate is displaced postero-inferiorly as evidenced from the relationship between the wing of the ambient cistern and the posterior colliculate bodies (→) Slight impression at the anterior aspect of the superior vermis evident



Fig 15 Huge pinealoma indenting the third ventricle and causing symmetric filling defect in the medial part of the bodies of the lateral ventricles

creased distance between these structures Slight *inferior displacement* and flattening of the quadrigeminal plate and the aqueduct were also evident (Fig 21)

Calcification is known to occur frequently in pinealomas The incidence was 69 per cent in the material of LOFGREN in agreement with 12 out of 18 pinealomas (67 per cent) in the present series Only in 2 pinealomas was the calci

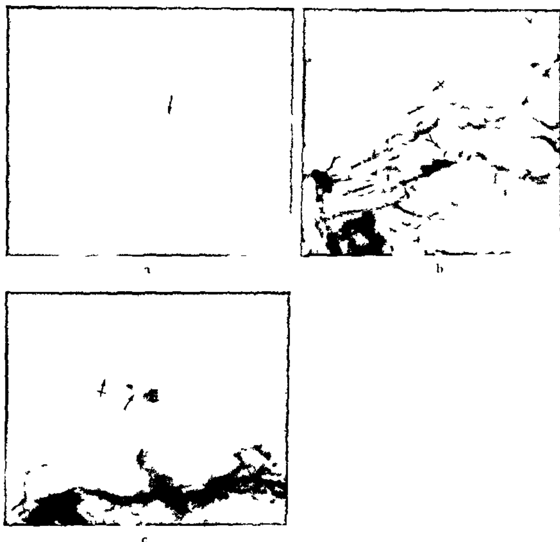


Fig. 16 a) Benign tumour of the pineal region, probably a pinealoma (aspiration biopsy). Polycyclic indentation of the posterior part of the third ventricle with calcification close to the deformed suprapineal recess. (This was the only pinealoma with calcification at the upper periphery of the tumour.) Aqueduct kinked at the level of the posterior colliculate bodies, which appear thickened (→), probably due to a humping effect. No obvious deformity of the superior vermis. b) and c) Same case, vertebral angiography. Slight postero-superior displacement of medial (↔) and lateral (→) posterior choroid arteries; vermian branches (>→) of superior cerebellar artery not displaced. c) Upward displacement of internal cerebral (→) and superior thalamic (↔) veins; the posterior mesencephalic and the precentral veins are not affected.

fication located in the upper part of the tumour and only in one case in its periphery (Figs 9 b, 16), in the remaining pinealomas the calcification was central or in the lower half of the tumour. Marked irregular calcification was observed in 1 pineoblastoma.



Fig 17 Huge pinealoma with marked postero-superior displacement of the medial choroid (⟶) as well as the lateral choroid (→) arteries Despite the size of the tumour no marked inferior displacement of the posterior cerebellar arteries or the vermis branches of the superior cerebellar arteries evident (>→)

Only 3 of the 9 gliomas (33 per cent) contained calcification The calcification in one case was in the central part of the growth and in 2 cases at its upper and posterior margin (Fig 9 a) Calcification in the periphery of the tumour was observed in 2 teratomas which also contained more centrally located calcification One papilloma with an irregular indentation in the third ventricle had calcification at its lower border (Fig 10)

Angiography Most anatomic structures in the pineal region are outlined by vessels filled at vertebral angiography These vessels are in the mid line the posterior pericallosal artery curving around the splenium of the corpus callosum and the medial posterior choroidal artery running in the roof of the third ventricle that is at the same level as the internal cerebral vein and the anterior part of the great vein of Galen The posterior limbs of the thalamic veins are situated close to the mid line The vermis branches of the superior cerebellar artery outline the superior part of the vermis with two limbs forming almost a right angle The position of the anterior surface of the cerebellum is also indicated by the pre central vein The distance between the posterior choroid arteries and the arteries of the vermis does not amount to more than a few millimetres The supratentorial part of the ambient cistern contains more laterally located vessels (Fig 11 b) such as the posterior cerebral artery and the proximal part of the medial and lateral choroid arteries the latter extending superiorly around the thalamus Located at about the same level are the basilar vein and the posterior mesencephalic vein receiving the lateral mesencephalic vein The posterior limit of the infratentorial part of the ambient cistern is

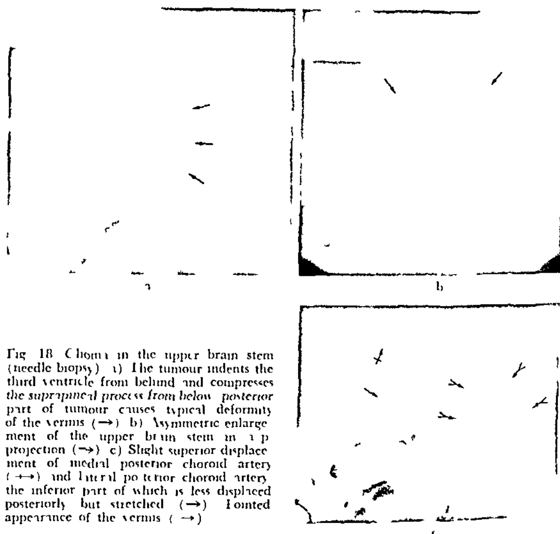


Fig 18 Glioma in the upper brain stem (needle biopsy) a) The tumour indents the third ventricle from behind and compresses *the suprapineal process from below* posterior part of tumour causes typical deformity of the vermis (→) b) Asymmetric enlargement of the upper brain stem in a p projection (→) c) Slight superior displacement of medial posterior choroid artery (→→) and lateral posterior choroid artery the inferior part of which is less displaced posteriorly but stretched (→) Pointed appearance of the vermis (→)

formed by the cerebellar hemisphere, which is identified by the hemispheric branches of the superior cerebellar artery with their step ladder appearance as they become foreshortened in the lateral view (MANI et coll 1968)

The thalamic veins *may be recognized in the frontal projection* in the early venous phase as they fill before most other veins due to the fact that they drain grey matter (WHITE et coll 1972) They may fill as early as the capillary phase, when the thalami are suffused with contrast medium (Fig 13) Due to the dense network of capillaries the accumulation of contrast medium in the posterior thalamus may, in the lateral projection resemble a tumour blush The true a p projection may display two limbs of the superior thalamic veins, one formed by the more anteriorly located laterally directed tributaries and the other by the main trunk with a more sagittal course (Figs 12, 13)

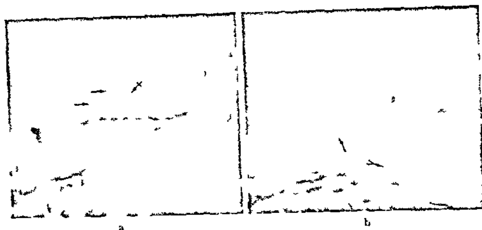


Fig 19 a) Malignant glioma of the upper brain stem Changes in the posterior choroid arteries similar but less obvious to those in fig 18 The shape of the vermis is difficult to ascertain in the arterial phase b) Marked posterior displacement of the pre central vein (>→) in the venous phase results in an increased distance between this and the posterior *mesencephalic vein* (→)

Vertebral angiography was carried out in 6 cases of pinealoma The superior thalamic veins and the great vein of Galen were displaced superiorly (Fig 16) in all cases although only to a slight extent in 2 of the cases One of these 2 cases had slight deformity of the vermis with a border probably concave forwards and identical to the case represented in Fig 5 There was also always postenor superior displacement of the posterior choroid arteries (Figs 16 17) The vessels at the level of the antero-inferior part of the ambient cistern, e g the posterior cerebral arteries and the basal and posterior mesencephalic vein were not significantly displaced in any of the 6 pinealomas This was true even with large tumours in which no obvious deformity of the vermis was present (Fig 17)

Seven cases of gliomas examined with vertebral angiography had changes similar to those evident with pinealomas The superior posterior displacement of the posterior choroid arteries and the superior thalamic and internal cerebral veins were however usually less marked in relation to the size of the tumour (Figs 19 20) On the other hand the deformity of the vermis as evident from the vermis branches of the superior cerebellar artery and the pre central vein was more marked the anterior surface being concave in all but 2 cases one of these was a glioblastoma in which the tumour vessels extended into the vermis indicating diffuse infiltration and the other a thalamic glioma The latter tumour and one additional glioma had caused inferior displacement of the basal vein and posterior cerebral artery on the affected side (Fig 23) The postero-superior

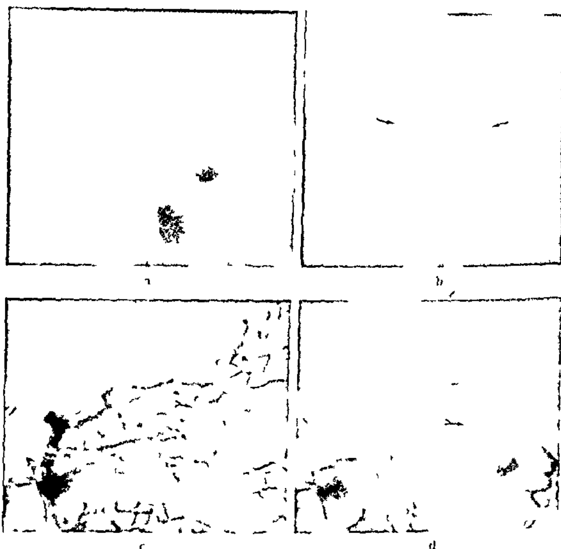


Fig. 20. Dysgerminoma of the collicular plate causing deformity of the vermis as evident in (a) from the *air outlining* the posterior limit of the tumour and the anterior surface of the vermis. Irregular *indentation* of posterior part of third ventricle, kinking of the aqueduct and inferior displacement of the *fourth* ventricle with decreased distance between the fastigium and the postero-superior recess. b) The tumour in a.p. projection surrounded by the ambient cisterns as an enlarged *part of the brain stem*; the dilated right choroid fissure is clearly evident. c) and d) Marked *deformity* of the upper vermis (>→) in the arterial and venous phases. Slight superior *displacement of the* medial choroid arteries and superior thalamic veins.

displacement of the posterior choroid arteries was less marked than in pinealomas and in 3 cases (Figs. 18, 19) the lateral choroid arteries were mainly displaced laterally and stretched. One dysgerminoma presented angiographic features similar to those of a glioma with marked deformity of the vermis (Fig. 20). One unverified tumour, not included in the material and probably a tera-

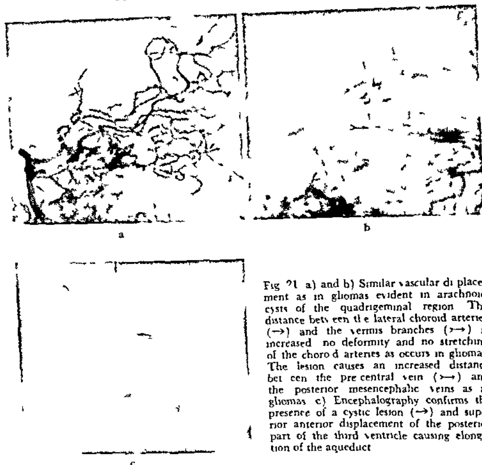


Fig 21 a) and b) Similar vascular displacement as in gliomas evident in arachnoid cysts of the quadrigeminal region The distance between the lateral choroid arteries (→) and the vermis branches (>→) is increased no deformity and no stretching of the choroid arteries as occurs in gliomas The lesion causes an increased distance between the pre central vein (>→) and the posterior mesencephalic veins as in gliomas c) Encephalography confirms the presence of a cystic lesion (→) and superior anterior displacement of the posterior part of the third ventricle causing elongation of the aqueduct

toma was associated with marked separation and supero-lateral displacement of the medial choroid arteries and thalamic veins (Fig 22) Obvious asymmetric growth was evident in the 2 tumours involving the thalamus the lateral choroid arteries and the superior thalamic veins being at different levels on the two sides The changes in the thalamic veins were described by GIUDICELLI et coll (1970) and were in accordance with the asymmetric displacement of the two internal cerebral veins reported by POTTS et coll (1963) Marked inferior displacement of the vessels in the choroid fissure may also be observed at carotid angiography (Fig 23) Most thalamic tumours also cause stretching of the anterior thalamo perforate arteries (WESTBERG 1969 Fig 24 a) This feature may be of importance in the differential diagnosis of large tumours in which the vascularity

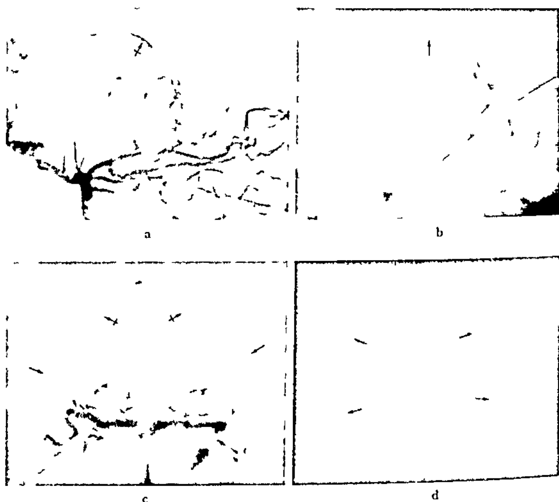


Fig 22 Unverified tumour of the upper brain stem probably a teratoma a) and c) The medial choroid arteries are much displaced superiorly and laterally (→→) The lateral choroid arteries (→) are less displaced b) Upper displacement of the great vein of Galen and the superior thalamic veins in venous phase d) Basilar veins displaced laterally indicating enlargement of the postero superior part of the brain stem (→)

is difficult to recognize, for example due to hypertrophy of feeding arteries (Fig 24)

Two arachnoid cysts posterior to the colliculate body were associated with deformity of the vermis similar to that of a glioma The posterior choroid arteries were displaced superiorly but otherwise unchanged, they were thus not stretched and without any other sign of malignant infiltration (Fig 21)

Meningiomas at the level of the tentorial notch may displace adjacent vessels within the ambient cistern in opposite directions Accordingly, the posterior cerebral artery may be displaced upwards and the superior cerebellar artery

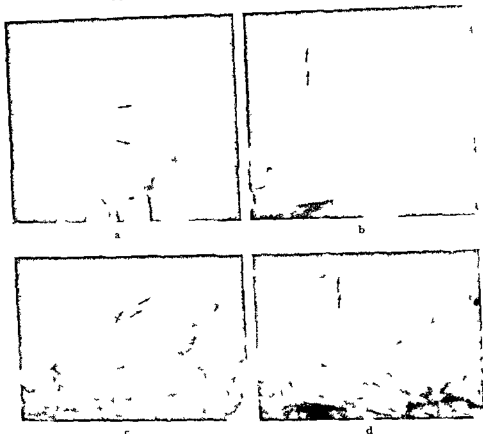


Fig 3 Glioma of the thalamus causing lateral displacement and flattening of the posterior pa t of the th d ventricle (a) The asymmetric growth of the tumour which reaches the foramen of Mon o is evident from the different positions of the floor of the lateral ven tricle formed by the thalamus on the two sides (b) This is less obvious in the arterial pha e (c) in wh ch the two lateral posterior choroid arteries (→) seem to reach about the same level Only one medial posterior choroid *artery* (⟷) *is well filled* d) The asymmetry of he *thalamus* is e ident from the position of the superior thalamic veins (→)

on the same side inferiorly which clearly indicates the extracerebellar nature of the lesion (Fig 26)

Although many of the tumours occurring in this area such as the pinealomas are usually vascular it is unusual for them to contain newly formed tumour vessels demonstrable at angiography this may however occur (Fig 27 b) The increased vascularity may sometimes be evident as enlargement of a feeding artery (Fig 27 a) Actual tumour vessels were pre ent only in glioblastomas (Fig 28) and metasta es (Fig 29)

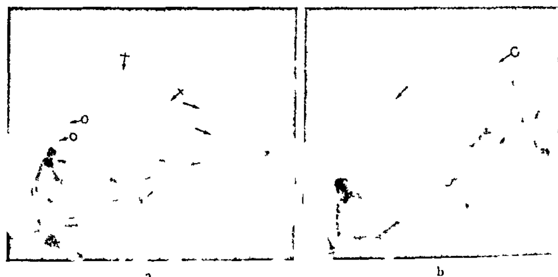


Fig. 24 a) Glioma of the thalamus causing posterior displacement and stretching of the lateral choroid arteries (→) and anterior displacement and stretching of the posterior thalamo-perforate arteries (o–). The medial posterior choroid artery (→→) is less displaced. Small pathologic vessels present in the centre of the tumour which seems to be fed by hypertrophied thalamic arteries. b) Glioblastoma of the splenium supplied by the hypertrophied and posteriorly displaced posterior pericallosal artery (ↄ→) and the inferiorly and anteriorly displaced posterior choroid arteries (→).

Discussion and Conclusions

The differential diagnosis of tumours in the pineal region depends on information obtained from the conventional skull examination and pneumography and angiography. Encephalography is preferable to ventriculography as it delineates that part of the tumour growing in the cisterns and provides more data on the deformity and infiltration of adjacent structures such as the vermis and the brain stem. Angiography is of particular importance when filling of the cisterns is incomplete and may also afford information as to the pathologic vascularization of the tumour.

Calcification seems to be more frequent in pinealomas than in gliomas; when located in the central or inferior part of the tumour, a pinealoma is more likely; when present in the upper part, another type of lesion is more probable. Asymmetric growth of a tumour disclosed by encephalography excludes a pinealoma and marked lateral displacement of the third ventricle indicates thalamic origin. Irregular indentation of the third ventricle is consistent with a glioma or a papilloma and a rounded or polycyclic appearance favours a pinealoma. Marked inferior displacement and deformity of the vermis rarely occurs with pinealomas, but is frequent in gliomas. A kink of the aqueduct and a humping up of the

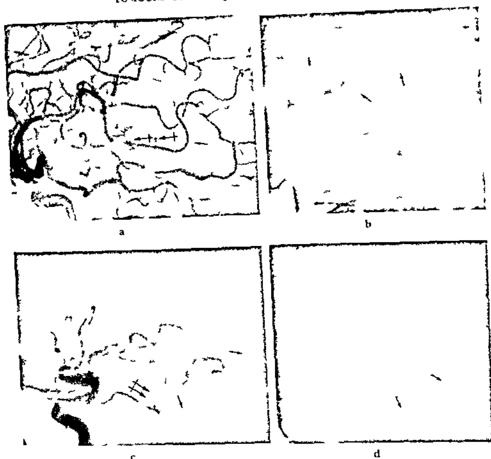


Fig 25 a) Glioma of the thalamus causing posterior displacement of the lateral ch ro d artery (→) and suppl ed by hypertroph ed thalamic arteries (+→) b) The tumour causes elevation of a subependymal vein probably the direct lateral c) Thalamic glioma with marked inferio and posterior displacement of the anterior cho oid artery (→) and hypertrophy and st etching of its thalamic b anches which ari e at right angles from the feeding artery (+→) d) The bas lar vein is displaced infe iorly a feature not evident with gliomas of the mesen cephalon

posterior colliculate body is an almo t constant finding in pinealomas in thala mic glioma the aqueduct frequently is displaced inferiorly and straightened

The vascular displacements of the lesions discussed have been summarized in a diagram (Fig 30) derived from vertebral angiography and indicates the vessels at three different levels tho e superior to the third ventricle tho e in the supratentorial part of the ambient cistern and those at the anterior aspect of the

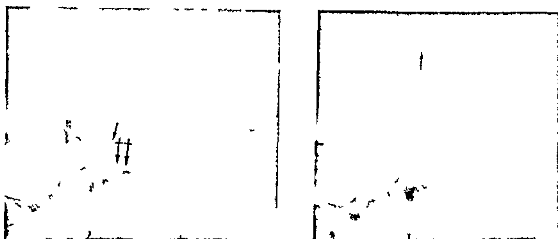


Fig. 26. Tentorial meningioma causing inferior displacement of the superior cerebellar artery (→→) and the posterior cerebral artery on one side (→) with superior displacement of the posterior cerebellar artery on the other side.

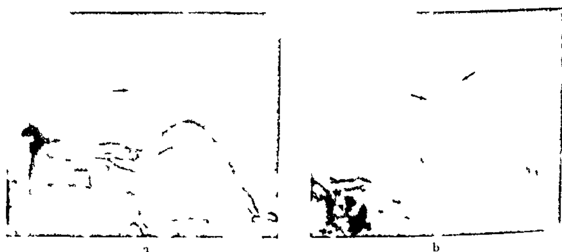


Fig. 27. a) The rich vascularization in this small glioma of the posterior thalamus and the mesencephalon is evident from the hypertrophy of the feeding lateral choroid artery. b) Small newly formed vessels fed from the choroid arteries in a pinealoma.

upper vermis. On the arterial side they may be said to be represented by (1) the posterior choroid arteries, (2) the posterior cerebral artery and (3) the vermian branch of the superior cerebellar artery. In the venous phase the corresponding vessels are (1) the superior thalamic vein and the great vein of Galen, (2) the basilar vein and the posterior mesencephalic vein and (3) the precentral vein. Inferior displacement of the vessels at all three levels, sometimes with increased distance between the second and third level may occur in *aqueduct stenosis* (HUANG 1969, GREITZ, to be published). A glioma of the brain stem is usually

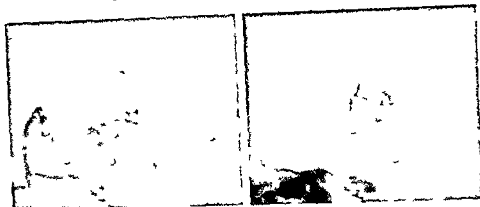


Fig 28 Irregular vessels in a glioblastoma causing asymmetric elevation of one of the superior thalamic veins

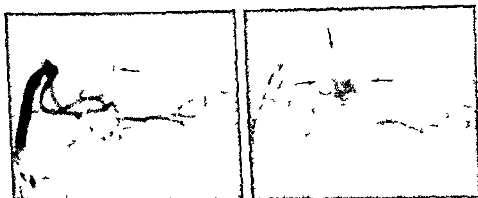


Fig 29 Richly vascularized metastases from a hypernephroma in the pineal region causing only minor vascular displacements

primarily associated with inferior posterior displacement of the vermian vessels and secondarily superior displacement of the vessels at the level of the third ventricle The opposite time sequence obtains for these changes in pinealoma Elevation of the vessels above the third ventricle is followed by inferior displacement of the vermian vessels Considerable upward displacement of the vessels adjacent to the upper posterior border of the thalamus usually occurs in thalamic gliomas inferior displacement of the vessels in the supratentorial part of the ambient cistern may also be recorded Displacement of the vermian vessels is usually less marked

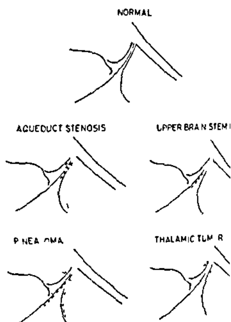


Fig 30 Vascular displacements in different lesions at the level of the posterior part of the tentorial notch Vessels are indicated at three different levels one superior level above the third ventricle represented by the medial posterior choroid artery the internal cerebral vein the superior thalamic veins and the great vein of Galen another level at the supratentorial part of the ambient cistern represented by the posterior cerebral artery the inferior parts of the posterior choroid arteries the basilar vein and the posterior mesencephalic vein and one third level at the superior anterior surface of the vermis represented by the vermian branch of the superior cerebellar artery and the pre central vermian vein

In conclusion it may be said that tumours of the upper dorsal brain s that is from the region of the colliculate plate and the aqueduct, may usuall distinguished from extracerebral lesions in this area, from tumours of splenium and from those of the upper vermis and as a rule also from tum arising in the thalamus The differential diagnosis is usually best mad encephalography Pinealomas are frequently difficult or impossible to disting from gliomas of the colliculate plate Vertebral angiography aids in the diffe tial diagnosis especially when filling of the cisterns is incomplete No si feature can be said to be specific for any particular type of tumour but t into consideration the type of deformity of the ventricular system the locatio the calcification in relation to the growth the displacement of the cisterns vessels and sometimes the presence of tumour vessels it is usually possibl reach a conclusion as to the extent and histology of the lesion This is of co of importance in the correct choice of treatment

Acknowledgements

The author is indebted to Prof Ingmar Wickbom for permission to include 5 cases amined by vertebral angiography and encephalography in the material This paper is b on one read at the XII International Congress of Radiology in Tokyo Japan 1969

SUMMARY

A review of the radiologic features of tumours in the quadrigeminal plate and adjacent structures is presented This is based on an autopsy material of 31 tumours arising in this area and investigations of 27 cases with ventriculography or encephalography and of 16 cases with verified pineal lesions examined with vertebral angiography The results are discussed with special reference to the differential diagnosis

ZUSAMMENFASSUNG

Es wird eine Übersicht zum röntgenologischen Erscheinungsbild von Tumoren der Vierhügelplatte und den angrenzenden Strukturen gegeben Diese gründet sich auf ein autoptisches Material von 31 Tumoren die von diesem Gebiet ausgegangen sind und auf Untersuchungen von 27 Fällen mit Ventrikulographie oder Encephalographie und von 16 Fällen mit nachgewiesenen pinealen Tumoren die durch vertebrale Angiographie untersucht worden waren Die Ergebnisse werden unter besonderer Berücksichtigung der Differentialdiagnose besprochen

RÉSUMÉ

L auteur passe en revue les signes radiologiques des tumeurs de la plaque quadrigeminal et des structures voisines Cette etude est basee sur un materiel d autopsie de 31 tumeurs prenant naissance dans cette région et sur l examen ventriculographique ou encéphalographique de 27 cas et sur l angiographie vertebrale de 16 cas de lesion pineale verifiee L auteur etudie ces resultats en particulier au point de vue du diagnostic differentiel

REFERENCES

DILENGE D et DAVID M L opacification des artères thalamiques au cours de l angiographie vertébrale Neuro Chir 6 (1965) 511

GALLOWAY J R and GREITZ T The medial and lateral choroid arteries Acta radiol 53 (1960) 353

— — and SJOGREN S E Vertebral angiography in the diagnosis of ventricular dilatation Acta radiol Diagnosis 2 (1964) 321

GIUDICELLI G and SALAMON G The veins of the thalamus Neuroradiology 1 (1970) 92

HUANG Y P and WOLF B S The veins of the posterior fossa — superior or galenic drainage group Amer J Roentgenol 95 (1965) 808

— — Precentral cerebellar vein in angiography Acta radiol Diagnosis 5 (1966) 250

— — ANTIN S P et coll Angiographic features of aqueductal stenosis Amer J Roentgenol 104 (1968) 90

JOHANSSON C The central veins and deep dural sinuses of the brain Acta radiol (1954) Suppl No 107

LAZORTHES G and SALAMON G The arteries of the thalamus An anatomical and radiological study Fourth International Congress of Neuroradiological Surgery Sept 1969 New York

LILIEQUIST B Encephalographic changes in the axial pressure cone syndrome Acta radiol 54 (1960) 369

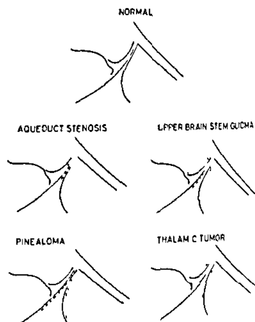


Fig 30 Vascular displacements in different lesions at the level of the posterior part of the tentorial notch Vessels are indicated at three different levels one superior level above the third ventricle represented by the medial posterior choroid artery the internal cerebral vein the superior thalamic veins and the great vein of Galen another level at the supratentorial part of the ambient cistern represented by the posterior cerebral artery the inferior parts of the posterior choroid arteries the basilar vein and the posterior mesencephalic vein and one third level at the superior anterior surface of the vermis represented by the vermian branch of the superior cerebellar artery and the precentral vermian vein

In conclusion it may be said that tumours of the upper dorsal brain stem, that is from the region of the colliculate plate and the aqueduct, may usually be distinguished from extracerebral lesions in this area, from tumours of the splenium and from those of the upper vermis and as a rule also from tumours arising in the thalamus The differential diagnosis is usually best made by encephalography Pinealomas are frequently difficult or impossible to distinguish from gliomas of the colliculate plate Vertebral angiography aids in the differential diagnosis, especially when filling of the cisterns is incomplete No single feature can be said to be specific for any particular type of tumour, but taking into consideration the type of deformity of the ventricular system the location of the calcification in relation to the growth, the displacement of the cisterns and vessels and sometimes the presence of tumour vessels, it is usually possible to reach a conclusion as to the extent and histology of the lesion This is of course of importance in the correct choice of treatment

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ROENTGENMICROGRAPHY OF THE HUMAN NEONATAL LUNG IN INFANTILE LOBAR EMPHYSEMA AND CYSTIC ADENOMATOID MALFORMATION

by

B ROBERTSON and SIGRID SODERLUND

Stereoscopic reconstruction of the peripheral parts of the bronchial tree by serial sectioning (BOYDEN 1967 1969) is a time-consuming procedure which for practical purposes must be limited to comparatively small tissue specimen Corrosion casts (LIEBOW et coll 1947) offer a more convenient approach, but have their obvious drawback in that the histologic aspect of the tissue is lost An alternative method stereo-roentgenmicrography is described in the present communication This technique which permits parallel radiologic and histologic investigations of the terminal airways was applied to a series of human neonatal lungs including the surgically resected specimens of two cases clinically diagnosed as infantile lobar emphysema

Methods The airways were injected via the lobar bronchus with a water suspension of 50 % fine barium sulfate (Micropaque) at a pressure of 20 mm Hg for a period of 15 to 60 seconds depending upon the size of the specimen Following the injection of the contrast medium the specimen was inflated with air and the bronchus was ligated The amount of air injected into the

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LOFGREN, F. O.: Vertebral angiography in the diagnosis of tumors in the pineal region. Acta radiol. 50 (1958), 108.

MANI, R. L., NEWTON, T. H. and GLICKMAN, M. G.: The superior cerebellar artery: an anatomic roentgenographic correlation. Radiology 91 (1968), 1102.

POTTS, D. G. and TAVERAS, J. M.: Differential diagnosis of space-occupying lesions in the region of the thalamus by cerebral angiography. Acta radiol. Diagnosis 1 (1963), 373.

WESTBERG, G.: The recurrent artery of Heubner and the arteries of the central ganglia. Acta radiol. Diagnosis 1 (1963), 949.

— Arteries of the basal ganglia. Acta radiol. Diagnosis 5 (1966), 581.

WHITE, E. and GREITZ, T.: Influence of the grey and white matter distribution in the drainage areas of the subependymal veins on their sequence of filling at angiography. Acta radiol. Diagnosis 13 (1972), 272.

WOLF, B. S., HUANG, Y. P. and NEWMAN, C. M.: The lateral anastomotic mesencephalic vein and other variations in drainage of the basal cerebral vein. Amer. J. Roentgenol. 89 (1963), 411.

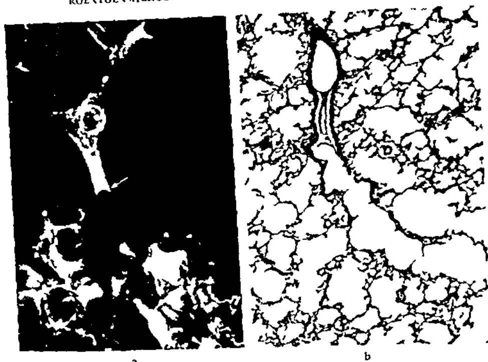


Fig Terminal airways in infantile lobar emphysema Corresponding *arrows in* (*a*) and (*b*) a) Roentgenmicrogram Abnormally slender bronchiolar outlines and overdistended alveoli × 5 b) Selected serial section from the same area Haematoxylin and eosin × 25

for infantile lobar emphysema the second surgical patient aged 2 days (birth weight 3470 g) was diagnosed clinically as having infantile lobar emphysema of the left lower lobe Histologic examination of the resected lobe however revealed that the enlargement was due to polycystic malformation of the pulmonary parenchyma the cystic space being covered with cuboidal or cylindrical epithelium of a bronchial type The histologic findings were thus interpreted as being due to cystic adenomatoid malformation of the lung

Results

The contrast filling of the bronchial tree was irregular in all specimens and in many areas the course of the bronchioles was masked by filled alveoli The terminal bronchioles were however in certain fields well demonstrated and their course could easily be examined with the stereomicroscope The regular airway appearance (Fig 1) was a consistent finding in the normal premature and full term lung specimens

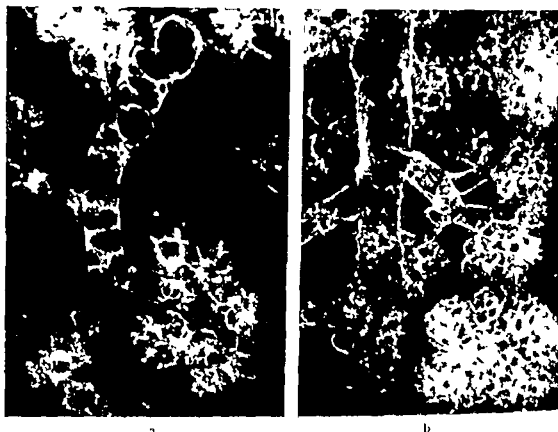


Fig. 1. Roentgenmicrograms of normal perinatal lungs. a) Premature infant (BW 1 790 g) × 2, b) Fullterm infant (BW 3 890 g). × 10.

bronchus varied from specimen to specimen. A moderate expansion of the parenchyma was attained; care was taken to avoid artificial rupture of the airways. The specimen was then fixed in 10 % neutral formalin. 2 mm thick cuts of the specimen were radiographed, and representative areas chosen for roentgenmicrography. The selected slices were embedded in a mixture of paraffin and beeswax, cut into 500 to 1 500 μ thick blocks and stereoscopic roentgenmicrograms obtained with Kodak Maximum Resolution Plates with a technique described in detail elsewhere (ROBERTSON 1968). Serial sections were cut from selected areas of the blocks in order to correlate the radiologic and histologic features of the terminal airways.

Material. A series of lung specimens from five neonatal autopsy cases (age still born to 1 month, birth weight 1 350 g to 3 890 g) without gross or histologic evidence of pulmonary disease was employed. The airway appearances of two surgically resected lung lobes were also examined. The first of these patients, aged 22 days (birth weight 4 080 g), had had the right middle lobe resected

The roentgenmicrographic findings in the single case of infantile lobar emphysema fail to permit of any general conclusion as to the etiology of the condition. The abnormally slender bronchioli demonstrated in this case might however support the view (RAYNOR et coll. 1967, CAMPBELL 1969) that structural abnormality of the bronchial walls leading to increased flaccidity is a possible pathogenic factor in this type of emphysema. The slender form might also be due to compression of terminal bronchioles by air trapping in the surrounding parenchyma. The latter interpretation is favoured by recent morphometric observations (HISLOP & REID 1970) which clearly indicate that the essential feature of at least certain forms of infantile lobar emphysema is polyalveolar pulmonary parenchyma.

A varying degree of cystic adenomatoid malformation is encountered in some lung lobes resected under the clinical diagnosis of infantile lobar emphysema (SODERLUND et coll. 1964). This is further illustrated by the case of the present series in which the greater part of the resected lobe was the seat of polycystic malformation. The differential diagnosis between infantile lobar emphysema and cystic adenomatoid malformation is often impossible on clinical grounds and may, due to the existence of transitional forms, be difficult even histologically.

Acknowledgement

This work was supported by The Swedish National Association for Heart and Chest Diseases.

SUMMARY

A roentgenmicrographic technique is described for stereoscopic reconstruction of the terminal bronchial tree of the normal and diseased lung of the neonate. Abnormally slender bronchioles were present in a lobe distended by infantile emphysema while distorsion of the bronchi characterised a lobe involved by cystic adenomatoid malformation.

ZUSAMMENFASSUNG

Es wird eine röntgenmikrographische Technik beschrieben, die für die stereoskopische Darstellung der Endbronchien der normalen und der abnormalen Lunge des Neugeborenen geeignet ist. Abnorm dünne Bronchiolen wurden in einem Lungenlappen gefunden, der durch infantiles Emphysem aufgeblasen war; in einem Lappen einer Lunge, in dem eine zystisch adenomatoide Missbildung vorlag, fanden sich verzerrte Bronchien.



Fig 3 Roentgenmicrogram of cystic adenomatoid *malformation of the lung Some* of the cystic spaces are outlined with contrast medium (arrow) Distorsion of the bronchial tree (right) × 10

Roentgenmicrograms from the case of infantile lobar emphysema revealed *overexpanded alveoli as well as an abnormally slender bronchial tree* (Fig 2) No other bronchial abnormalities were evident nor was there any cystic malformation of the pulmonary parenchyma In roentgenmicrograms from the case of cystic adenomatoid malformation, some of the cystic spaces were well outlined with contrast medium, indicating a communication between the cysts and the bronchial tree The cystic structures appeared to compress and distort the adjacent bronchial branches (Fig 3)

Discussion

An important obstacle to the examination of the roentgenmicrograms obtained with the present technique is caused by the irregular distribution of contrast medium in the specimens Masking due to its excess in the alveoli, prevents the radiologic analysis of the bronchial tree in many areas, and it remains uncertain whether the lobuli that are best demonstrated are representative of the entire specimen

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EXPERIMENTAL OCCLUSION OF THE CORONARY ARTERIES IN THE CLOSED CHEST DOG

A selective method

by

ALFRED SZAMOSI

The observation of the development of collateral pathways under experimental conditions is of both theoretical and practical interest. A simple technique will be described for the occlusion or constriction of the lumen of major branches of coronary arteries without thoracotomy, one that may be applied to other vessels accessible to a catheter and thus obviating the need for surgical exposure.

Methods. The experiments were performed in mongrel dogs weighing 15 to 30 kg. Intravenous anaesthesia with thiopentotalnatrium and tracheal intubation was followed by the animals being placed in the left lateral recumbent position. The right common carotid artery was exposed and cannulated with a teflon catheter (Kifa ID 1.8 mm, OD 2.3 mm), the tip of which was placed in the ascending aorta just above the valves. The ECG and arterial blood pressure were continuously monitored and recorded at regular intervals (Elema EMT 465 pressure transducer, EMT 460 amplifier, Mingograf 42 B). Serial coronary angiography was then performed in order to define the anatomy of the coronary vessels and serve for later comparison. All angiographies were performed ad modum NORDENSTRÖM (1960). Thus the technique involved the elevation of

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RÉSUMÉ

Les auteurs présentent des techniques roentgenmicrographiques pour la reconstruction stéréoscopique de l'arbre bronchique terminal du poumon normal et pathologique du nouveau-né Il y avait des bronchioles anormalement grêles dans un lobe distendu par l'emphysème infantile alors que la distorsion des bronches caractérisait un lobe atteint par la malformation kystique adénomatoïde

REFERENCES

BOYDEN E A Notes on the development of the lung in infancy and early childhood Amer J Anat 121 (1967) 749

— *The pattern of the terminal air spaces in a premature infant of 30—32 weeks that lived nineteen and a quarter hours* Amer J Anat 126 (1969) 31

CAMPBELL P E Congenital lobar emphysema Austr Paediat J 5 (1969), 226

HISLOP A and REID L New pathological findings in emphysema of childhood 1 Polyalveolar lobe with emphysema Thorax 25 (1970) 682

LIEBOW A A HALES M R LINDSKOG G E and BLOOMER W E Plastic demonstrations of pulmonary pathology Bull int Ass Med Museums 27 (1947) 116

RAYNOR A C CAPP M P and SEALY W C Lobar emphysema of infancy Ann thorac Surg 4 (1967) 374

ROBERTSON B The intrapulmonary arterial pattern in normal infancy and in transposition of the great arteries Acta paediat scand (1968) Suppl No 184

SODERLUND S ROBERTSON B and BORLESCHI R Infantile lobar emphysema Acta paediat scand (1964) Suppl No 159 p 89

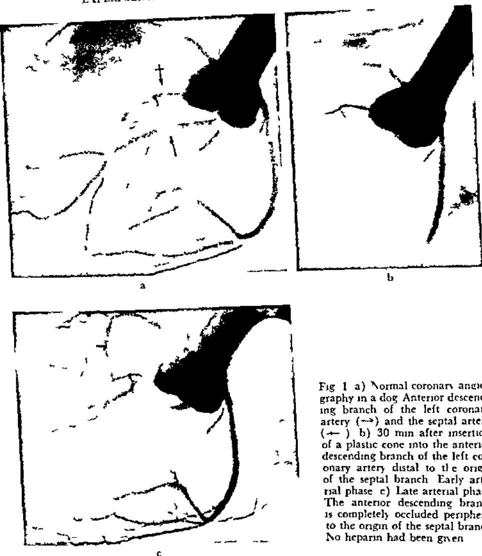


Fig 1 a) Normal coronary angiography in a dog Anterior descending branch of the left coronary artery (→) and the septal artery (←) b) 30 min after insertion of a plastic cone into the anterior descending branch of the left coronary artery distal to the origin of the septal branch Early arterial phase c) Late arterial phase The anterior descending branch is completely occluded peripheral to the origin of the septal branch No heparin had been given

ventricular ectopic beats ventricular tachycardia and elevation of the ST segment of the ECG were always evident at varying intervals after the procedure Major infarctions of the myocardium developed in all dogs surviving the first 24 hours At autopsy the lumen of the plastic cone was invariably occluded by clots Clotting and obstruction of the lumen developed probably within a few minutes after the introduction of the cones irrespective of the

the intrabronchial pressure to about 45 cm H_2O just before as well as during the injection of the contrast medium in order to diminish the blood flow in the aorta

The gross anatomy of the coronary arteries was examined and a branch suitable for occlusion selected The inner diameter of this vessel at the site of the planned occlusion was measured with a millimeter scale directly on the film and corrected for geometric enlargement The animals were then given heparin intravenously in a dose of 250 IU/kg body weight The catheter used for angiography was then replaced by a polythene catheter fitted with a suitable curved tip The second catheter (Kifa, red Ödman Ledin) was introduced under fluoroscopic control into the coronary artery branch previously selected A metal guide wire was then advanced through the catheter in such way that its soft tip reached well beyond the planned site of occlusion and the polythene catheter was removed A plastic cone fitted with a longitudinal channel was then threaded on the free end of the guide wire and gently pushed by a soft polythene catheter until it was held in a wedged in position, the guide wire was then withdrawn The polythene catheter was then also removed, so that the cone was left in the lumen of the preselected coronary artery branch

The cones used for vessel occlusions were 4 to 8 mm in length with a basal diameter of 2 to 4 mm, the tip being smoothly tapered off to facilitate introduction, the cone was so selected that its outer diameter corresponded approximately to the inner diameter of the vessel segment to be occluded (Figs 1 to 3) The channel through the longitudinal axis of the cone was wide enough to permit the passage of the guide wire with a minimum amount of friction Cones made of various materials, e g teflon polythene and heparin treated polythene (LAGERGREN et coll 1968) and with different sizes of the central channel were tested as well as stainless steel balls with bore holes (Fig 4) (The results of these tests will be published separately)

The teflon catheter was then reintroduced into the ascending aorta and a second coronary angiography performed Dogs surviving for longer periods underwent repeat coronary angiographies at various intervals ranging from one week to one year Post mortem examination of the heart was always performed

Results

Occlusion of a major coronary artery branch was successfully performed in all twelve experiments in which it was possible to cannulate the anterior descending or circumflex branch of the left coronary artery This manoeuvre was unsuccessful in two early experiments (not now included), probably because the dogs were too small (under 10 kg) Marked ECG changes, such as

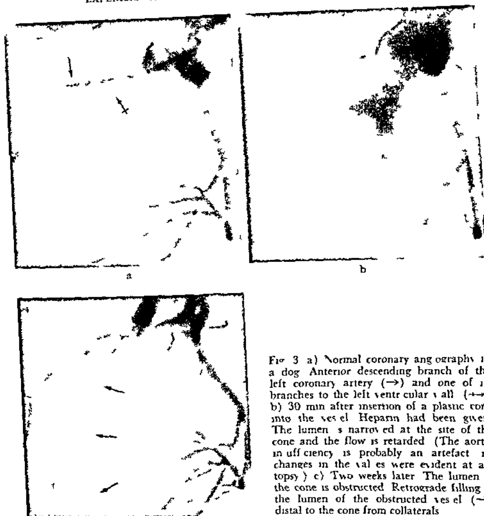


Fig. 3 a) Normal coronary angiography in a dog. Anterior descending branch of the left coronary artery (→) and one of its branches to the left ventricular wall (+→). b) 30 min after insertion of a plastic cone into the vessel. Heparin had been given. The lumen is narrowed at the site of the cone and the flow is retarded. (The aortic insufficiency is probably an artefact: no changes in the valves were evident at autopsy.) c) Two weeks later. The lumen of the cone is obstructed. Retrograde filling of the lumen of the obstructed vessel (→) distal to the cone from collaterals

JACOBEY et coll. 1962), stainless steel balls (RIBELIMA 1964) resulting in instant occlusion of small branches of the coronary artery. Thrombosis of a large branch may be produced by passing a weak direct current between an intraluminal positive electrode and a negative one sited externally on the chest wall (SALAZAR 1961).

The difficulties of reproducing in animals the mechanisms involved in human disease have often been pointed out. While important differences are recognized, it is agreed that the investigation of events in experimental coronary artery

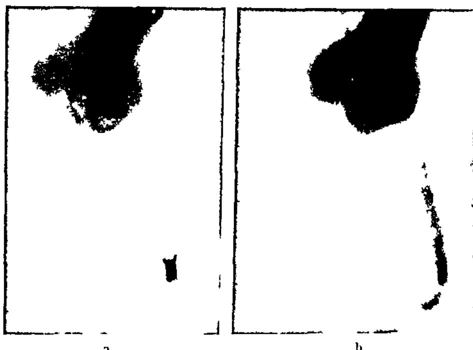


Fig 2 a) A short funnel shaped teflon tube inserted into the circumflex branch of the left coronary artery 30 min before angiography Beginning of the injection of contrast medium b) 1 5 s later The flow through the circumflex branch is slightly retarded due to the narrowing of the lumen by the teflon tube Heparin had been given previously

material chosen in dogs with normal coagulation reactions (Fig 1) When heparin had been administered, the same events may have occurred after the cessation of the anticoagulant effect (Figs 2, 3)

Discussion

Several methods for experimental occlusion of the coronary arteries have been described and may roughly be divided into two groups

(1) Those requiring thoracotomy and direct exposure of the vessel Some of these make possible a slow or graded construction of the arterial lumen (Blair et coll 1964, Blum et coll 1938 Blumgart et coll 1950, Gacl et coll 1956, Litvak & Vineberg 1959, Malm et coll 1960, Mautz & Gregg 1937, Vineberg et coll 1960)

(2) Those not requiring thoracotomy Most of these involve cannulation of one of the coronary arteries and injection of a suspension of small particles, e g lycopodium spores (Guzman et coll 1962, Hammer & Pisa 1962, West et coll 1962), plastic spherules (Agress et coll 1952, Herzberg et coll 1966,

The technique described seems to meet the above requirements Certain other circumstances are worth mentioning The procedure is simple and may be used by those familiar with modern cardiovascular catheterization techniques The material shape and size of the foreign body used for occlusion is not limited to those mentioned The only prerequisites are a lumen permitting easy passage of the guide wire a suitably rounded off tip and a smooth surface to facilitate insertion and advancement The maximum permissible diameter of the vessel to be occluded is determined by the size of the entry vessel e g that of the common carotid artery in the present experiments The lumen of the occlusive body may be made as small as desired the only limiting factor being the availability of a fine yet sufficiently rigid guide wire

Tests are now in progress to use plastic bodies to the surface of which heparin has adsorbed (LAGERGREN et coll 1968) The success of such experiments should open up the possibility of achieving graded coronary artery constriction without thoracotomy Another approach with the same objective may be the use of anticoagulants during prolonged treatment of the experimental animal

There are a limited number of human conditions in which treatment aims at the preservation of naturally occurring lumina of the body e g occlusive vascular disease of the extremities stenosis of the cerebral aqueduct or on the other hand at the occlusion of such lumina e g certain types of bleeding aneurysms and arteriovenous malformation The experiments described in this paper were performed during 1966—67 PORTSMANN et coll (1967) reported the ingenious application of an essentially similar method in the successful treatment of persistent ductus arteriosus DOTTER (1969) introduced coilspring endarterial grafts in the femoral artery in dogs with the aid of a technique based on the same principle The simplicity of the procedure seems to warrant still further exploration as to its possibilities for experimental as well as therapeutic purposes

A description of the detailed angiographic findings in coronary occlusion and their relationship to changes evident at autopsy will be the subjects of a separate paper

Acknowledgements

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SUMMARY

A simple method of experimental occlusion of deep blood vessels that are accessible to the catheter has been used in the coronary and pulmonary artery branches of dogs The technique includes the use of occlusive bodies of various sizes shapes and materials these being inserted through an exposed peripheral vessel and led by a guide wire into the desired position



Fig. 1. a) Detail of pulmonary angiography in a normal dog. b) A stainless steel ball 6 mm in diameter, with a narrow channel has been inserted into the artery of the lower lobe by the method described. Two segmental arteries are occluded.

occlusion may provide substantial contributions to the understanding of human coronary artery disease.

The significance of certain factors in experiments such as the angiographic demonstration and evaluation of collateral vessels should be emphasized. Thus, (1) the technique employed should not involve pericardiotomy lest vessel-rich adherences develop between the layers of pericardium and myocardium. It should preferably not include thoracotomy either, so as to avoid haemodynamic changes. (2) An extensive area should be made ischaemic by occlusion of one large coronary artery branch, so that large and numerous collateral vessels will develop, facilitating angiographic demonstration in vivo. (3) Instead of random occlusion governed by unpredictable haemodynamic events and anatomic variations (as may happen when particles are injected into a coronary artery), the technique should permit the free selection of the site of the occlusion; this is to produce an ischaemic area of optimal size in a region allowing easy angiographic demonstration (without disturbing the superimposition of extracardiac structures, e.g. the vertebral column). (4) The occlusion should persist throughout a prolonged experiment, thus maintaining the pressure gradient over the site of obstruction.

MALM A OHLSSON N M SJOSTROM B et coll Experimental coronary thrombosis Electrocardiographic coronary arteriographic and histopathologic study in the dog Acta chir scand 1?0 (1960) 36

MAUTZ F R and GREGG D E The dynamics of collateral circulation following chronic occlusion of coronary arteries Proc Soc exp Biol 36 (1937) 797

NORDENSTROM B Contrast examination of the cardiovascular system during increased intra bronchial pressure Acta radiol Suppl (1960) No 200

PORSTMANN W WIERNY L und WARNKE H Der Verschluss des Ductus arteriosus persistens ohne Thorakotomie Thoraxchirurgie 15 (1967) 199

RIBELIMA J Selective embolization of the coronary arteries A haemodynamic metabolic and radiolo ic study Proc Soc exp Biol 117 (1964) 367

SALAZAR A E Experimental myocardial infarction Induction of coronary thrombosis in the intact closed chest dog Circulat Res 9 (1961) 13o1

VINEBERG A MAHANTI B and LITVAK J Experimental gradual coronary artery constriction by ameroid constrictors Surgery 47 (1960) 765

WEST J W KOBAYASHI T and ANDERSON F S Effects of selective coronary embolization on coronary blood flow and coronary sinus venous blood oxygen saturation in dogs Circulat Res 10 (196?) 7?2

ZUSAMMENFASSUNG

Eine einfache Methode der experimentellen Okklusion der tiefen Blutgefasse die fur den Katheter erreichbar sind wurde bei den Kranzgefassen und den Asten der Pulmonalarterie des Hundes verwendet Die Technik umfasst den Gebrauch verschliessender Korper von verschiedener Grosse Form und von verschiedenem Material welche durch ein freigelegtes peripheres Gefass eingefuhrt werden und durch einen Fuhrungsdraht in die gewunschte Position geleitet werden

RÉSUMÉ

L auteur a utilise au niveau des arteres coronaires et des branches de l artere pulmonaire de chiens une methode simple d obstruction experimentale de vaisseaux sanguins profonds qui sont accessibles au catheterisme Cette technique comprend l emploi de corps obstructifs de dimensions de formes et de natures variables ces corps sont introduits par denudation d un vaisseau peripherique et sont conduits par un guide metallique jusqu à la situation desiree

REFERENCES

Agress C M Rosenberg M J Jacobs N J and Schneiderman A Protracted shock in the closed chest dog following coronary embolization with graded microspheres Amer J Physiol 170 (1952) 536

Blair E Nygren E and Cowley R A A spiral wire technique for producing gradually occlusive coronary thrombosis J thorac cardiovasc Surg 48 (1964) 476

Blum L Schauer G and Calef B Gradual occlusion of a coronary artery an experimental study Amer Heart J 16 (1938) 159

Blumgart H L Zoll P M Freedberg A S and Gilligan D R The experimental production of intercoronary arterial anastomoses and their functional significance Circulation 1 (1950) 10

Dotter Ch T Transluminally placed coilspring endarterial tube grafts Long term patency in canine popliteal artery Invest Radiol 4 (1969) 329

Gage A A Olsson K C and Chardack W M Experimental coronary thrombosis in the dog The description of a method Ann Surg 143 (1956) 533

Guzman S V Swenson E and Jones M Intercoronary reflex Demonstration by coronary angiography Circulat Res 10 (1962) 739

Hammer J and Pisa Z A method of isolated gradual occlusion of a main branch of a coronary artery in closed chest dogs Amer Heart J 64 (1962) 67

Herzberg R M Rubio R and Berne R M Coronary occlusion and embolization effect on blood flow in adjacent arteries Amer J Physiol 210 (1966) 169

Jacobey A J Taylor W J Smith G T et coll A new therapeutic approach to acute coronary occlusion I Production of standardized coronary occlusion with microspheres Amer J Cardiol 9 (1962) 60

Lagergren H Egberg N Eriksson J C and Gillberg G Preparation and evaluation of nonthrombogenic surfaces J thorac cardiovasc Surg 56 (1968) 381

Litvak J and Vineberg A Experimental gradual arterial occlusions with in vitro and in vivo observations Surgery 46 (1959) 953

Table 1

Mean ECG response in 24 consecutive patients examined with left selective coronary angiography after injection of Urografin 60 Isopaque 290 and Isopaque 290 without calcium

	Before angiography	During angiography		
		Urografin 60	Isopaque 290	Isopaque 290 without calcium
No of patients	24	24	24	14
QRS axis	+20	—7	—7	+1
QRS vector	6 5	11 1	11 2	9 2
T axis	+68	+123	+117	+115
T vector	4 4	20 6	13 3	13 7
Heart rate	81 7	70 7	66 3	70 0
QT duration	39 2	45 6	42 6	44 4

after elective coronary injection of Urografin 60 % in the present work were compared with those resulting from the selective coronary injection of Isopaque 290 and Isopaque 290 without calcium ions Isopaque 290 corresponds to Isopaque Coronar diluted to 290 mg I/ml and prepared for experimental purposes only

Material and Methods The ECG registrations were recorded during selective coronary angiography in 24 consecutive patients by the JUDKINS technique (1967) The contrast media used were Urografin 60 % and two Isopaque Coronary solutions modified in that they possessed the same viscosity osmolality and iodine content as Urografin 60 % One of these had the same proportion of sodium methylglucamine and calcium salts as Isopaque Coronar and was labelled Isopaque 290 the other modification was Isopaque 290 without calcium The viscosity of Urografin 60 % was 7 0 centipoise at 20° C and 4 1 centipoise at 37 C while the viscosity of Isopaque 290 and Isopaque 290 without calcium was 6 8 centipoise at 20 C and 3 9 centipoise at 37° C The osmolality of Urografin 60 % was 1 52 osmol compared to 1 54 osmol for the two other contrast media

The ECG responses to the three different contrast media were investigated in 24 consecutive patients The responses from coronary injections of Urografin 60 % and Isopaque 290 were correlated in 24 patients examined with left (Table 1) and in 8 patients with right selective coronary angiography (Table 2) A correlation was also made between the ECG responses resulting from injection of Urografin 60 % and Isopaque 290 without calcium into the left coronary artery in 14 patients (Table 1) Each injection consisted of 7 ml

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ELECTROCARDIOGRAPHIC CHANGES DURING SELECTIVE CORONARY ANGIOGRAPHY

A comparison between Urografin 60% and Isopaque 290 without calcium ions

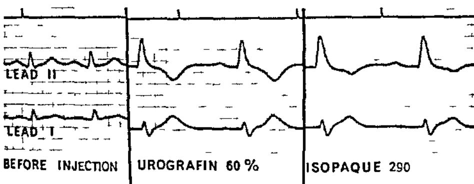
by

H. EIE, H. GRENDAHL, A. NORDVIK and C. MÜLLER

The toxicity of triiodinated contrast media, widely used in selective coronary angiography, is markedly reduced by the addition of methylglucamine (BJORK et coll. 1967, BROWN et coll. 1967, GENSINI & DIGIORGI 1964, JACOBSSON & PAULIN 1967 b). The contrast media used in this investigation were Urografin 60 % and the two derivatives of Isopaque Coronar, both containing sodium and methylglucamine in the proportion of about 1 to 6, but differing in their cationic characteristics. Urografin is a diatrizoate and Isopaque Coronar a metrizoate. Animal experiments have indicated that the LD_{50} increases when calcium ions are added (SALVESEN et coll. 1967).

A characteristic ECG response occurs during injection in selective coronary angiography (COSKEY & MAGIDSON 1967, FERNANDEZ et coll. 1968, GRENDAHL et coll. 1972, JACOBSSON & PAULIN 1967 a, MACALPIN et coll. 1966). The most obvious changes consist of a shift in the QRS and T axes and an increase in the vectors and QT duration. The response is probably due to a direct physiochemical action of the medium, and has been described by GRENDAHL et coll. in their investigation of Urografin 60 %. The ECG responses

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ECG standard lead I and II from a patient before selective coronary angiography and during right coronary injection with Urografin 60 and Isopaque 290 The T amplitude is higher durin the injection of Urografin 60 than with the latter

60 % than during Isopaque injections The difference was statistically significant ($p < 0.01$ $t = 3.32$) The marked increase in the T vector during the coronary injection of Urografin 60 % was thus due to both an increase in amplitude and the duration of the T wave (see Figure)

When the coronary injection was made into the left coronary artery the T axis deviated towards + 120 but no significant difference was evident in the response to either of the three contrast media The QRS complex also responded in the same manner to all the media The axis deviated counter clockwise and the vector was on an average doubled The heart rate slowed during the coronary injections and slightly more after the Isopaque media than following Urografin 60 % The difference was however not statistically significant

Isopaque 290 and Isopaque 290 without calcium were compared in 14 patients and no significant difference was evident in any of the responses mentioned the T vector was markedly higher during the coronary injection of Urografin 60 % than with Isopaque 290 without calcium being 18 4 and 13 7 respectively The difference is significant ($0.05 < p < 0.01$ $t = 2.90$)

Only a limited number of comparative examinations were carried out during right elective coronary angiography (Table 2) and no statistical analysis was therefore performed It appears that the increase in the T vector is more marked and the heart rate somewhat higher during the coronary injection of Urografin 60 % than with Isopaque 290

Cardiac arrythmia was not encountered during the investigation and no serious complications occurred One patient had a transient atrioventricular block of three seconds duration after the injection into the right coronary artery

Table 2

Mean ECG response in 8 consecutive patients examined with right selective coronary angiography after injection of Urografin 60 % and Isopaque 290

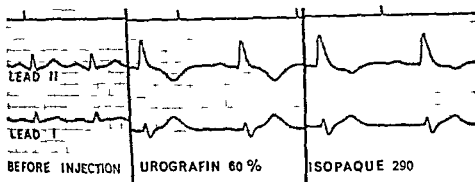
	Before angiography	During angiography	
		Urografin 60	Isopaque 290
No. of patients	8	8	8
QRS axis	+16	+79	+80
QRS vector	[illegible]	[illegible]	9.6
T axis	+104	−66	−59
T vector	3.0	20.4	[illegible]
Heart rate	83.5	[illegible]	[illegible]
QT duration	36.2	[illegible]	41.8

contrast medium introduced under manual pressure, the two contrast media to be compared being injected without change in the position of the patient and with an interval of approximately 15 minutes between the injections. Standard ECG lead I and II were recorded during the injection on an Elema Mingograf 81 at a paper speed of 50 mm/second. Vectors were calculated in Ashman units and the Student's t test was used for the statistical analysis. Ten of the patients had aortic valvular disease, 2 cardiomyopathy, 7 coronary disease and 5 patients, examined for possible angina pectoris, had no organic heart abnormality.

Results

The most obvious change in the ECG response produced by the coronary injection of either of the three contrast media appeared in the amplitude of the T waves. The T vector was significantly higher after the injection of Urografin 60 % than after either of the Isopaque media. During left coronary angiography the T vector after the injection of Urografin 60 % averaged five times and after either Isopaque media three times the T vector before each angiography (Table 1). This difference is statistically significant ($p < 0.01$, $t = 3.91$). The T vector after injection of Urografin 60 % was higher than the T vector after either Isopaque medium in 20 patients, the T vectors were equal in one patient and in 3 patients the Isopaque media caused the highest T vector response.

The QT-interval was increased during injection of all three contrast media due to a prolonged duration of the T wave and was longer during Urografin



ECG standard lead I and II from a patient before selective coronary angiography and during right coronary injection with Urografin 60 and Isopaque 290 The T amplitude is higher during the injection of Urografin 60 than with the latter

60 % than during Isopaque injections The difference was statistically significant ($p < 0.01$ $t = 3.32$) The marked increase in the T vector during the coronary injection of Urografin 60 % was thus due to both an increase in amplitude and the duration of the T wave (see Figure)

When the coronary injection was made into the left coronary artery the T axis deviated towards + 120 but no significant difference was evident in the response to either of the three contrast media The QRS-complex also responded in the same manner to all the media The axis deviated counter clockwise and the vector was on an average doubled The heart rate slowed during the coronary injections and slightly more after the Isopaque media than following Urografin 60 % The difference was however not statistically significant

Isopaque 290 and Isopaque 290 without calcium were compared in 14 patients and no significant difference was evident in any of the responses mentioned the T vector was markedly higher during the coronary injection of Urografin 60 % than with Isopaque 290 without calcium being 18.4 and 13.7 respectively The difference is significant ($0.05 < p < 0.01$ $t = 2.90$)

Only a limited number of comparative examinations were carried out during right selective coronary angiography (Table 2) and no statistical analysis was therefore performed It appears that the increase in the T vector is more marked and the heart rate somewhat higher during the coronary injection of Urografin 60 % than with Isopaque 290

Cardiac arrythmia was not encountered during the investigation and no serious complications occurred One patient had a transient atrioventricular block of three seconds duration after the injection into the right coronary artery

of Isopaque 290. Another patient developed a slow nodal rhythm with a heart rate of 38 per minute following the injection of the same contrast medium into the left coronary artery.

Discussion

Distinct but transient changes appear in the ECG during selective coronary angiography. The QRS axis moves counter-clockwise during left and clockwise during right selective coronary angiography, and the QRS axis is doubled compared with the ECG registrations made before the coronary angiographies. The T axis during injection of the left coronary artery moves towards a direction of + 120° and during right coronary injection towards — 60°. When Urografin 60 % is used in selective coronary angiography the T-vector increase from five to seven times (GRENDAHL et coll.). The ECG response is caused by the medium exclusively and is not a reaction to hypoxia during the injection (GRENDAHL et coll.).

The present comparative investigation of Urografin 60 % and the two Isopaque media indicates that the change in the T wave, both with respect to amplitude and duration, is significantly more marked during the coronary injection of Urografin 60 % than with the Isopaque media, the T vector on an average is about 50 per cent higher with Urografin 60 %. The increase in amplitude and duration of the T wave probably indicates a delay in repolarization in the myocardium, which has been perfused by the contrast media. The distinctly different changes during the coronary injection of Urografin 60 % may therefore indicate that the delay in repolarization is more marked during coronary injections of Urografin 60 % when compared with the two Isopaque media.

The osmolality, viscosity and iodine content were the same in all three media employed. The most distinct difference was the content of calcium ions added to Isopaque 290. When the ECG response after coronary injection with Isopaque 290 was compared with that following Isopaque 290 without calcium ions, no statistical difference was evident in the ECG response. The calcium content of Isopaque 290 cannot therefore be responsible for the changes in the T-wave that result from the injection of Urografin 60 %. The different ECG response is therefore more likely caused by the chemical difference between Urografin 60 % being a diatrizoate and Isopaque 290 a metrizoate.

It is notable that the displacement in the T axis was the same during the injection of the two media employed while the change in the T-vector was different. This may indicate that the shift in the T axis observed during the selective angiography depends on the anatomy of the coronary arteries and the

magnitude of the myocardial areas perfused by these vessels while the change in the T vector is more dependent on the electro physiologic effect of the media

No definite conclusions can be drawn with regard to the clinical importance of the observations although a distinct difference in ECG response was observed between Urografin 60 % and the two I opaque media The transient changes in the QRS and T waves in the ECG during the selective coronary angiography seem not to be related to any serious complication and the magnitude of the ECG changes produced by any of the media used in the investigation was probably not related to any possible toxic effect No difference in the clinical condition of the patients was apparent as a result of coronary injection with Urografin 60 % nor the two Isopaque media and the angiograms appeared to be of equal quality

SUMMARY

ECG standard leads I and II were recorded during right and left coronary angiography to determine any changes that might occur following the injection of Urografin 60 % Isopaque 290 and Isopaque 290 without calcium ions The material consisted of 24 patients No untoward effects of the contrast media were apparent

ZUSAMMENFASSUNG

EKG Standardableitungen I und II wurden während Angiographie der rechten und linken Koronararterien registriert um eventuelle Veränderungen die nach Injektion von Urografin 60 % Isopaque 290 und Isopaque 290 ohne Kalzium Ionen auftreten können festzustellen Das Material umfasst 24 Patienten Es waren keine nachteiligen Effekte dieser Kontrastmittel nachweisbar

RÉSUMÉ

Les auteurs ont enregistré au cours d angiographies coronariennes droites et gauches les dérivations standard I et II de l électrocardiogramme afin de déceler toutes les modifications qui peuvent se produire après l injection d Urografin 60 % d Isopaque 290 et d Isopaque 290 sans ions calcium Ils ont ainsi examiné 24 sujets les moyens de contraste n ont pas entraîné d effets nocifs décelables

REFERENCES

BJORK L CAMERINI F and LARINI G P Electrocardiographic changes during left heart and aortic angiocardiography with Urografin 76 and Isopaque 60 % Angiology 18 (1967) 96

BROWN T G HOPPE J O and BORISENOK W A Cardiovascular studies of Isopaque B and other radiopaque media Acta radiol (1967) Suppl No 270 p 58

COSKEY R L and MACIDSON O Electrocardiographic response to selective coronary angiography Brit Heart J 29 (1967), 512

FERNANDEZ F, BESSEDE A CHARPENTIER F et coll Modification de l electrocardiogramme au cours de l artériographie coronaire sélective Arch Mal Cœur 61 (1968) 504

GENSINI G G and DIGIORGI S Myocardial toxicity of contrast agents used in angiography Radiology 82 (1964) 24

GRENDAHL H LIE H NORDVIK A and MULLER C Electrocardiographic changes during selective coronary angiography Acta med scand 191 (1972) 493

JACOBSSON B and PAULIN S (a) Experiences with different contrast media in coronary angiography Acta radiol (1967) Suppl No 270 p 103

— — (b) Experiences with different contrast media in coronary angiography Acta radiol (1967) Suppl No 270 p 194

JUDKINS M P Selective coronary angiography Radiology 89 (1967) 815

MACALPIN R N WEIDNER W A KATTUS A A and HANAFEE W N Electrocardiographic changes during selective coronary cineangiography Circulation 24 (1966), 627

SALVESEN S LUND NILSEN P and HOLTERMANN H Effects of calcium and magnesium ions on the systemic and local toxicities of the N methyl glucamine (meglumine) salt of metriozoic acid (Isopaque) Acta radiol (1967) Suppl No 270 p 180

FROM ROENTGEN DEPARTMENT I (DIRECTOR PROF O BARTLEY) SAHLGRENSKA SJUKHUSET AND THE LABORATORY OF EXPERIMENTAL BIOLOGY OF THE DEPARTMENT OF ANATOMY THE UNIVERSITY OF GOTHENBURG SWEDEN

THERMOGRAPHY AND MICROANGIOGRAPHY IN THE INVESTIGATION OF LOCAL TOXIC EFFECTS OF CONTRAST MEDIA AND ANAESTHETICS

by

S E SORENSEN and K NILSSON

Examination procedures in diagnostic radiology often imply that contrast media come in intimate contact with more or less injured tissue e g the *urethral* and bladder mucosa and that of the cervix uteri as well as with the uterine cavity and uterine tubes Contrast media may also be deposited accidentally into normal tissue perivascularly at intravenous or intraarterial injections

Contrast media commonly in use for diagnostic purposes in the lower urinary tract and often applied in combination with local *anaesthetics are* potent drugs that may affect the tissue locally One with a lowered threshold injury after earlier surgical intervention infection etc is especially sensitive to further damage the process of healing may also be disturbed by *alterations in* the local environment

The immediate toxic effects of different drugs after *their* local application to the tissue of the cheek pouch of the hamster has been investigated by BRANEMARK et coll (1969) and SORENSEN (1971) This tissue is sensitive to injury of any kind and vital microscopic analysis of *the tissue* injury phenomena as well

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as the determination of the permeability disturbances in the *microvessels of the* pouch revealed even slight damage (BRÅNEMARK 1966, BRANEMARK et coll 1966, SORENSEN) This biologic test model has thus provided valuable information about the local toxic properties of certain contrast media and locally applied anaesthetics (BRANEMARK et coll, SORENSEN) The investigations attributed some of the adverse effects to the hypertonicity of the solutions The local toxicity of anaesthetics and contrast media used in urethrography and hysterosalpingography e g the contrast medium as such (Diodone) as well as the vehicle, proved to be extremely toxic to the tissue in the area where the drugs were deposited It was actually demonstrated that some media in routine use in diagnostic radiology caused such severe tissue changes in the deposit area that no restitution of microvascular structure and function could be demonstrated during the whole observation period of 5 hours More or less complete destruction of the tissue in the deposit area was sometimes observed

These observations suggested that it might be important to investigate the effect of different contrast media and local anaesthetics commonly in use by a test model not so sensitive to injury as the tissue of the cheek pouch of the hamster The ear of the rabbit was chosen as the biologic test site since this tissue was considered to provide adequate reactivity levels and to possess suitable sensitivity The local reaction was analysed by infrared thermography to evaluate the immediate effects of the application of the different solutions into the tissue (BRÅNEMARK 1965, 1966, BIRCH et coll 1968, 1969, BRANEMARK & NILSSON 1969, NILSSON 1970) Microangiography (LUNDSKOG et coll 1968, BIRCH et coll 1968, 1969) was employed to investigate and evaluate *the long* term tissue injury effects of the drugs

As some of the side effects of contrast media given intravascularly have been attributed to their hypertonicity, hypertonic sodium chloride solutions iso osmolar to some of the contrast media were also investigated The local anaesthetics and contrast media used in urethrography and *hysterosalpingography* consist of more than one pharmacologically active substance An attempt was therefore made to determine the local damaging effect caused by each of these individual substances in addition to their combined action The solutions examined appear in Table 1

Method Rabbits *weighing approximately 1 5 to 2 0* kg were used The ears were gently shaved and 0 1 ml of the solution to be examined deposited into the tissue between the cartilage and the perichondrium with a fine needle Two examinations of every medium were performed, the drug being injected proximally in one ear and distally in the other The contrast medium and the *iso osmolarly corresponding* sodium chloride solution were injected in the same animal when an attempt was made to compare their local toxicity Similarly the

Table 1

Contrast media and anaesthetics used in the investigation

Contrast media used intravascularly

Contrast medium	Iso-osmolar sodium chloride solution
Urografin 30	2 56
Urografin 45	4 09
Urografin 60	5 59
Urografin 76	7 67
Biligrafin forte	
Isopaque 260	
Isopaque Cerebral	
Isopaque 350	
Isopaque Coronar	

Local anaesthetics

Local anaesthetics (commercial preparation)	Anaesthetic component	Vehicle
Xylocain Gel	Xylocain 2	Methylcellulose Gel
Carbocain Thesat Gel	Carbocain 1 5	
	Thesat 1 0	
	Carbocain Thesat (1 5 + 1 0)	Methylcellulose Gel

Contrast media used in diagnostic radiology of the female genital tract and the lower urinary system

Contrast medium (commercial preparation)	Contrast substance	Vehicle
Endografin		
Perjodal S	Diodone (125 mgI/ml)	Dextran (130 cSt)
Perjodal U	Diodone (175 mgI/ml)	Dextran (400 cSt)

Perjodal S and Perjodal U media Xylocain Gel and Carbocain Thesat Gel, Dextran and Methylecellulose Gel solutions as well as the anaesthetics Xylocain 2 % and Carbocain 1 5 % were investigated in the same animal

After deposition of the solutions the animals were placed in a holding box with the ears in a non compressing frame for macrophotography and thermography Thermography was performed with an AGA Thermovision infrared camera model 669 at a distance of approximately 55 cm from the ear

The state of the ears was recorded daily for seven days by photography with transillumination and by thermography On the seventh day microangiography was performed as follows The rabbit was anaesthetized with about 100 mg Nembutal intravenously An incision was made through the abdominal wall and

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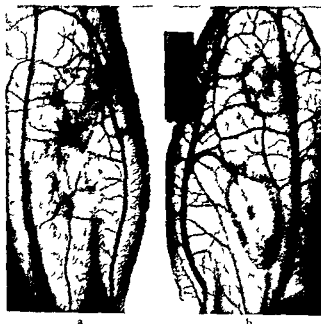


Fig a) Increased translucency in transilluminated rabbit's ear after deposition of two drugs of high viscosity b) Encircled areas denote characteristic changes in transilluminated ear tissue with decreased translucency after deposition of contrast media such as Diodone and anaesthetics such as Carbocain Thesat

Results

Macrophotography and thermography A macrophotogram of the ear of the rabbit taken in transillumination and a corresponding thermogram of the same ear appear in Fig 1 Vessels under 100 to 200 μ in diameter did not appear as individual structures in the thermogram though they presumably helped to produce the background heat emission of the ear An increased translucency of the tissue in the deposit area could be demonstrated with media of high viscosity (Fig 2 a) After deposition of Carboxymethylcellulose Gel Perjodal S and Dextran of 130 cSt viscosity the deposit area in the ear seemed macroscopically normal after 3 to 4 days In all other instances that is after deposition of the local anaesthetics Xylocain Gel and Carbocain Thesat Gel as they are known commercially the contrast media Perjodal U and Endografin and the vehicle Dextran with a viscosity of 400 cSt some kind of macroscopically discernible tissue abnormality remained during the whole observation period of seven days (Fig 2 b) A pathologic reaction of the tissue in the region where the solutions were injected could also be demonstrated after deposition of the

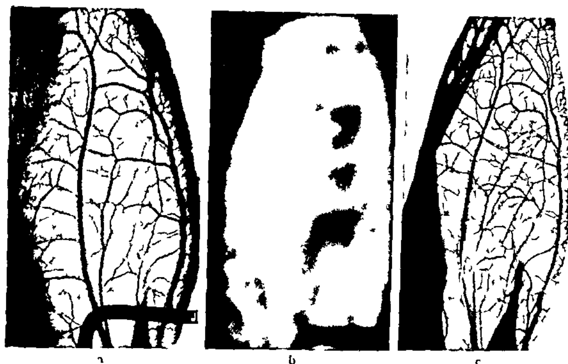


Fig. 1. Normal ear of rabbit. a) Macrophotogram in transillumination. b) Thermogram. c) Microangiogram of vascular system.

the aorta exposed and cannulated with a fine polythene catheter. Approximately 2 ml of equal quantities of Heparin (2,500 IU/ml) and Xylocain 0.5 % were introduced through the catheter. A suspension of constantly agitated Micropaque (25 %, 1 part barium sulphate to 4 parts physiologic saline filtered through a pyrex filter of porosity 1) was then introduced into the catheter at a controlled constant pressure of about 130 cm water, which was just above the arterial pressure of the rabbit of 110 to 120 cm of water. Both external jugular veins were divided and the rabbit was allowed slowly to exsanguinate over a period of 30 to 40 minutes as the Micropaque gradually filled the intravascular space, the infusion was continued about 30 minutes after the death of the animal, an average of 250 ml Micropaque being introduced. The ears were then clamped at their bases with large compressing forceps and severed from the head proximal to the forceps.

The ears were placed with the outer sides on Kodak MR roentgen film covered with thin aluminium foil. They were then irradiated with a Machlett OEG 50 tube at a distance of 120 mm at 12 kV and 15 mA for 15 minutes. The macrophotographs, thermograms and microangiograms were analysed and compared.

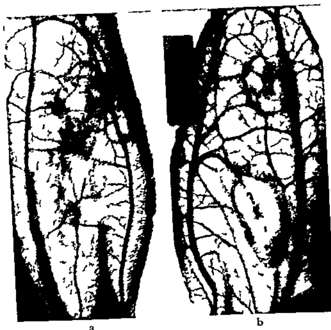


Fig 2 a) Increased translucency in transilluminated rabbit s ear after deposition of two drugs of high viscosity b) Encircled areas denote characteristic changes in transilluminated ear tissue with decreased translucency after deposition of contrast media such as Diodone and anaesthetics such as Carbocain Thesat

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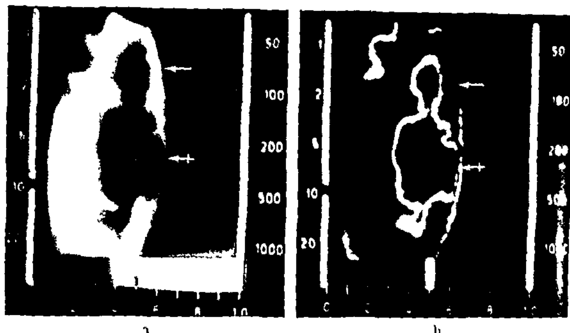


Fig 3 a) Characteristically decreased infrared emission over areas of rabbit's ear one day after deposition of Xylocain 2 % (⟶) and Xylocain Gel (⟶) b) The same ear at the same time with the deposit areas identified by isotherm settings

contrast media Diodone (125 mg I/ml) and Diodone (175 mg I/ml), the *Carbocain Thesat solution (1 5 % + 1 0 %)*, the *Thesat solution (1 0 %)*, Xylocain 2 % and Biligrafin forte

The heat emission of the ear was not affected to any demonstrable degree by the different concentrations of sodium chloride, Urografin, Isopaque and Biligrafin forte A normal thermogram was also obtained over areas injected with the contrast medium Perjodal S, the Dextran solution with a viscosity of 130 cSt and the Carboxymethylcellulose Gel solutions

Areas with temperatures substantially lower than normal could be demonstrated in the deposit area as well as distal to this region (Fig 3) after deposition of Xylocain 2 %, Perjodal U, Endografin, Xylocain Gel and Carbocain Thesat Gel, the contrast substances Diodone 125 mg I/ml and 175 mg I/ml as well as the vehicle Dextran with a viscosity of 100 cSt This pathologic thermogram however changed to normal within 3 to 4 days in the ears in which Xylocain 2 %, Xylocain Gel, Endografin and Carbocain Thesat Gel were deposited whereas in the other cases the appearances became normal by one to 2 days

Carbocain-Thesat (1 5 % + 1 0 %) and Thesat (1 0 %) caused quite other thermographic appearances Immediately after deposition of these solutions into the tissues an increased emission was evident from extensive areas over the ear The temperature of the ear rose from the second to the fifth day and

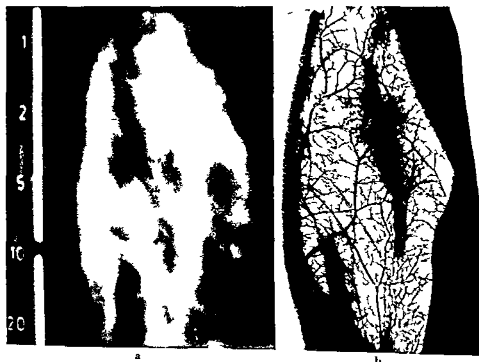


Fig 4 a) Characteristic infrared emission with double-contour of main central vessels over a rabbit s ear two days after deposition of Carbocain Thesat and Thesat b) The same ear with the vascular system identified by microangiography on the 7th day after deposition

macroscopic signs of inflammation were demonstrated in the thermogram by a characteristic double contour of the vessels (Fig 4)

Microangiography The normal appearances are presented in Fig 1 Lower concentrations of the intravascular contrast media Urografin and Isopaque as well as the hypertonic sodium chloride solutions iso-osmolar to all the contrast media examined failed to influence the vascular bed as demonstrated in the microangiograms

The high concentrated contrast media Urografin 76 % and Isopaque 350 as well as Isopaque Coronar produced a rich network of small vessels in the deposit area (Fig 5) The local anaesthetics Carbocain Thesat Gel and Xylocain Gel U and the contrast media Diodone 125 mg I/ml and 175 mg I/ml, the vehicle Dextran with a viscosity of 400 cSt the Carboxymethylcellulose Gel solutions the contrast media Biligrafin forte and Endografin proved to be more damaging

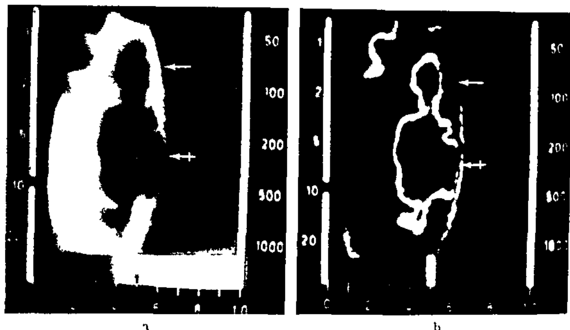


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Fig 6 Detail of microangiogram Characteristic appearances of central necrosis and marginal network of a large number of wide tortuous newly formed vessels at deposit of Carbocain Thesat Gel (Cf microangiogram in fig 5 b)

1968 JEPPSSON & OLIN 1970) Relatively few reports have attempted to analyse the local toxic effects of contrast media and local anaesthetics

Earlier experimental investigations (BRANEMARK et coll SORENSEN) performed on the tissue of the cheek pouch of the hamster have indicated that contrast media and local anaesthetics cause disturbances in the microvascular structure and function The intensity of these changes varies from slight to profound dysfunction in the microcirculation with stasis of long duration in the microvessels increase in capillary permeability and sometimes even destruction disorganization and disintegration of structural and cellular components in the deposit area

It appears reasonable to suppose that the acute effects caused by deposition of some of the contrast media and local anaesthetics onto the tissue of the cheek pouch of the hamster might result in more or less permanent damage to the tissues in the deposit area The present investigation is a continuation of earlier experiments in tissue toxicity (BRANEMARK et coll SORENSEN) the aim being to explore the long term effect of different solutions (contrast media and local anaesthetics) used in diagnostic radiology It is obvious from the present experimental investigation that there are great differences in tissue toxicity between the various contrast media and local anaesthetics currently in use The results obtained are in agreement with earlier reports on the acute toxic properties

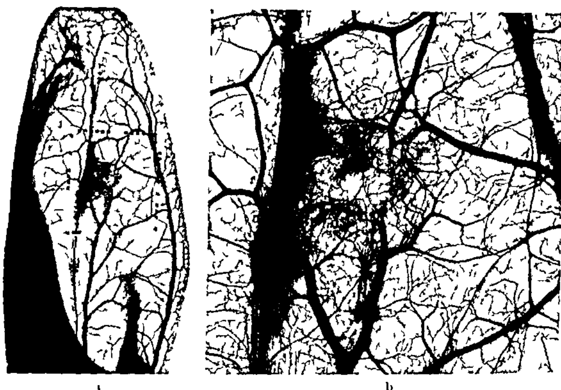


Fig. 5. a) Microangiogram of rabbit's ear one week after deposition (area indicated by dotted line) of Urografin 76 %. b) Higher magnification. The microvascular system is characterized by changes in the vessels and by the formation of a large number of new vessels distributed over the whole field, even in the central area of the deposit.

to the tissues. They all caused a central area of necrosis surrounded by a zone characterized by a rich network of small vessels in the deposit region (Fig. 6). Perjodal S and Xylocain 2 % initiated the development of the same network of small vessels in the deposit area but did not produce central necrosis. The vehicle Dextran with a viscosity of 130 cSt and the local anaesthetic Carbocain (1.5 %) failed to affect the tissue of the ear to any microangiographically demonstrable degree. The results obtained by macrophotography, thermography and microangiography appear in Table 2.

Discussion

All the water soluble iodinized contrast media and local anaesthetics currently used are known to cause side effects and complications and the radiologic literature contains numerous experimental and clinical observations on the toxicity of the former (Brown et coll. 1965, Toda et coll. 1965, Krovetz et coll. 1967, Gritz et coll. 1967, Lindgren et coll. 1968, Braunwald et coll.



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Table 2

Microvascular and tissue effects in the rabbit ear analysed by macrophotography, thermography and microangiography. — no demonstrable reaction, + demonstrable reaction. + in the microangiogram indicates changes of the vessels in the deposit area and the formation of a rich network of newly formed vessels (fig. 5). ++ central necrosis in deposit area with marginal increase of vascularity (fig. 6).

	Macrophotography	Thermography	Microangiography
Urografin 30	—	—	—
Urografin 45 %	—	—	—
Urografin 60 %	—	—	—
Urografin 76 %	—	—	+
Biligrafin forte	+	—	++
Endografin	+	+	++
NaCl solution 2.56 %	—	—	—
NaCl solution 4.09 %	—	—	—
NaCl solution 5.59 %	—	—	—
NaCl solution 7.67 %	—	—	—
Isopaque 260	—	—	—
Isopaque Cerebral	—	—	—
Isopaque 350	—	—	+
Isopaque Coronar	—	—	+
Xylocain Gel	+	+	++
Xylocain 2 %	+	+	+
Gel (Astra)	+	—	++
Carbocain Thesit Gel	+	+	++
Carbocain Thesit (1.5 % + 1.0 %)	+	+	++
Carbocain (1.5 %)	—	—	—
Thesit (1.0 %)	+	+	++
Gel (Bofors)	+	—	++
Perjodal S	+	—	+
Perjodal U	+	+	++
Diodone (125 mgI/ml)	+	+	++
Diodone (175 mgI/ml)	+	+	++
Dextran (130 cSt)	+	—	—
Dextran (100 cSt)	+	+	++

of the media examined in the cheek pouch of the hamster (BRANEMARK et coll., SORENSEN).

Macrophotography with transillumination proved to be accurate in demonstrating the state of the tissue in the deposit area after the administration of

solutions of increased viscosity The local effect caused by the media of low viscosity could however not always be demonstrated by this registration procedure

Thermography has been used extensively in clinical medicine (BOWLING BARNES & GERSHON COHEN 1963) Primary and secondary malignancy (especially of the breast) (STRAX 1964, CONNELL et coll 1966 NOTTER & MELANDER 1966 JONES 1969) peripheral vascular diseases (BRANEMARK BRANEMARK & NILSSON ROSENBERG & STEFANIDES 1964, SKVERSKY et coll 1964) localized inflammation (LAWSON & GASTON 1964) and wound healing (GOLDIE et coll HOLM PEDERSEN et coll) have all been investigated BIRCH et coll have demonstrated that a specially adapted thermographic apparatus AGA Thermovision infrared camera model 669 may be used in examining small vessels that the individual vessels in the ear of the rabbit down to a size of a hundred micra in diameter may be revealed and that the temperature variations in and around the vessels may be measured with an accuracy of 0 2° C

Only the media that from earlier experimental investigations in the cheek pouch of the hamster were known to be highly toxic against the tissues caused any alteration in heat emission detectable by thermography Two changes due to pathology were demonstrated the most common reaction was a lowering of the temperature over the deposit area and in some cases peripheral to and distal to this region This effect of the media deposited into the tissues may be explained by their toxic action on the microvessels with more or less reduced local circulation There may therefore be justification for supposing that the heat emission decreases locally An analysis of the respective contribution to this alteration in heat production caused by change in local cell metabolism and blood circulation was however not possible BIRCH et coll considered that local cell metabolism in the ear of the rabbit plays only a small role in the heat production and that heat is brought to the ear mainly by the circulating blood The Carbocain Thesat solution (1 5 % + 1 0 %) and the Thesat solution (1 0 %) caused quite another type of reaction The appearances were those of irritation of the ear a general (but slight) increase in heat emission and a disturbed and ever changing thermographic condition A thermogram of the rabbit ear characterized by a double contour of the vessels and a disturbed non stabilized emission often occurs in inflammatory conditions The results obtained in this investigation are in good agreement with those with the cheek pouch of the hamster on the toxicity of the Thesat solutions Furthermore, considering that Thesat is a surface tension drug presumably promptly diffusing out into the tissues of the ear it is reasonable to assume that it exerts its effect over a large area to produce a general state of tissue inflammation

Microangiography has been widely used as a technique for investigating the

microcirculation (SAUNDERS & MONTAGNA 1964, BELLMAN et coll 1961, BIRCH et coll) BRANEMARK et coll discussed the validity of microangiography as a method of producing an exact representation of the microvascularity They stated that all the larger vessels could be filled with contrast medium, but that only some of the true capillaries (2 to 15 μ in diameter) could be demonstrated They also reported that the luminal diameter appeared smaller in the microangiograms than in vital microscopic investigations, a difference that ranged from 10 to 50 % However they concluded that provided these limitations were taken into consideration the method was a useful one in microvascular research

Microangiography appeared in the present work to be a reliable method of revealing the response of the tissue of the rabbit ear after deposition of various contrast media and local anaesthetics It is obvious from the results that only some of the media deposited caused damage that could be detected

The intensity of the reaction ranged from the development of a network of small vessels (Fig 5) to more or less complete loss of tissue substance (Fig 6) The experimental model used possessed a sensitivity level adequate for investigating the tissue toxicity of contrast media used in diagnostic radiology of the lower urinary tract and the female genital system as well as of the surface anaesthetics Xylocain Gel and Carbocain Thesat Gel administered in combination with these media The solutions that caused reactions to the ear of the rabbit were those that in earlier experimental investigations proved to be so toxic as to produce complete or incomplete irreversible damage to the tissue in the cheek pouch of the hamster analysed by vital microscopy as well as disturbances in microvascular permeability (SORENSEN)

The results of the present investigation do not permit any comparison of the tissue toxicity between the local anaesthetics Xylocain Gel and Carbocain Thesat Gel The toxicity of Carbocain Thesat (1 5 % + 1 0 %) is however definitely greater than that of Xylocain 2 % The tissue injury caused by the Carbocain Thesat solution (1 5 % + 1 0 %) is considered to be due mainly to the Thesat content This conclusion is based on earlier experimental investigations on the toxicity of Carbocain (1 5 %) in the tissue of the cheek pouch of the hamster (SORENSEN), the absence of any thermographic reaction to Carbocain in the tissue of the ear, and to the fact that damage to the tissue could not be demonstrated by microangiography

The Diodone solutions with an iodine concentration of 125 mg I/ml and 175 mg I/ml are toxic against the tissue to a degree demonstrable by the rabbit ear test model It should be noted in this connection that the modern contrast media — diatrizoate and metrizoate solutions — with an iodine concentration corresponding to that of the Diodone solutions failed to cause any damage to the tissue of the ear demonstrable by thermography or by microangiography

The present limited number of experiments is insufficient for a comparison of the tissue toxicity of the different vehicles. It should however be noted that Perjodal S (containing as contrast medium Diodone with an iodine concentration of 125 mg I/ml) caused a tissue reaction with the development of a rich network of vessels in the deposit area but no loss of tissue substance; this was contrary to the reaction produced by Perjodal U (a contrast medium with an iodine concentration of 175 mg I/ml). Furthermore the Dextran solution with the lowest viscosity (130 cSt) failed to produce any demonstrable tissue reaction as against the strong reaction produced by Dextran with a viscosity of 400 cSt. These findings are consistent with the results earlier reported by SORENSEN on the effect of these solutions on the tissue of the cheek pouch of the hamster. It was concluded that the Dextran solution of the highest viscosity was the most toxic to the tissues of the pouch.

Conclusion

This experimental investigation indicates that the contrast media used in diagnostic radiology of the lower urinary tract and the female genital system are toxic when applied to the tissues of the ear of the rabbit. The surface anaesthetics Carbocain Thesat Gel and Xylocain Gel also cause damage. The typical tissue reaction in the thermogram was a lowering of the temperature in the deposit area. A tissue substance defect was registered by microangiography. The contrast media given intravascularly produced no detectable microangiographic reaction except for the high concentrated solutions that produced a weak tissue reaction appearing as a rich network of small vessels in the deposit area.

The clinical interpretation of the present results should be made with some reserve. It is perhaps remarkable that Diodone, long ago rejected as a contrast medium for intravascular use, still appears to be the medium of choice in the examination of the lower urinary tract and the female genital organs. The results now obtained support the earlier expressed opinion (SORENSEN) that it is time to consider the possibility of using metrizoate or diatrizoate solutions as contrast media as radiologic diagnostic substances for local application.

Acknowledgements

The authors take this opportunity of thanking Nyegaard & Co A/S, Oslo, Schering AB, Stockholm, Pharmacia AB, Uppsala, Astra AB, Sodertalje and Bofors Nobel Pharma AB, Molndal who placed the contrast media, local anaesthetics and other material at their disposal. This work was supported by the Swedish Medical Research Council.

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The intensity of the reaction ranged from the development of a network of small vessels (Fig. 5) to more or less complete loss of tissue substance (Fig. 6). The experimental model used possessed a sensitivity level adequate for investigating the tissue toxicity of contrast media used in diagnostic radiology of the lower urinary tract and the female genital system as well as of the surface anaesthetics Xylocain Gel and Carbocain Thesit Gel administered in combination with these media. The solutions that caused reactions to the ear of the rabbit were those that in earlier experimental investigations proved to be so toxic as to produce complete or incomplete irreversible damage to the tissue in the cheek pouch of the hamster analysed by vital microscopy as well as disturbances in microvascular permeability (SORENSEN).

The results of the present investigation do not permit any comparison of the tissue toxicity between the local anaesthetics Xylocain Gel and Carbocain Thesit Gel. The toxicity of Carbocain Thesit (1.5 % + 1.0 %) is however definitely greater than that of Xylocain 2 %. The tissue injury caused by the Carbocain Thesit solution (1.5 % + 1.0 %) is considered to be due mainly to the Thesit content. This conclusion is based on earlier experimental investigations on the toxicity of Carbocain (1.5 %) in the tissue of the cheek pouch of the hamster (SORENSEN), the absence of any thermographic reaction to Carbocain in the tissue of the ear, and to the fact that damage to the tissue could not be demonstrated by microangiography.

The Diodone solutions with an iodine concentration of 125 mg I/ml and 175 mg I/ml are toxic against the tissue to a degree demonstrable by the rabbit ear test model. It should be noted in this connection that the modern contrast media — diatrizoate and metrizoate solutions — with an iodine concentration corresponding to that of the Diodone solutions failed to cause any damage to the tissue of the ear demonstrable by thermography or by microangiography.

— Albrektsson B Lindstrom J and Lundborg G Local tissue effects of wound disinfectants Acta chir scand (1966) Suppl No 357 p 166

Braunwald E Gorlin R McIntosh H D et coll Cooperative study on cardiac catheterization Circulation 37 (1968) Suppl No 3 p 93

Brown R Rahimtoola S H Davis G D and Swan H J C The effect of angiocardiographic contrast medium on circulatory dynamics in man Cardiac output during angiocardiography Circulation 31 (1965) 234

Connell J F Ruzicka F F Grossi C E et coll Thermography in the detection of breast cancer Cancer 19 (1966) 83

Foda M T Castillo C A Corliss R J et coll The intravascular pressure response in man to contrast substance used for angiocardiography Amer J med Sci 250 (1965) 390

Goldie I Brunius U and Nilsson K Early reactions in skin incisions in the rat To be published

Greitz T Telenius R and Tornell G Influence of methylglucamine and calcium ions in metrizoate (Isopaque) on the bradycardial effect in carotid angiography *In* Cations in intravascular contrast media and development of specific metrizoate formulas Acta radiol (1967) Suppl No 270 p 208

Holm Pedersen P H Nilsson K and Brånemark P I The microvascular system of healing wounds in young and old rats To be published in Advanc Microcirc

Jeppsson P G and Olin T Neurotoxicity of roentgen contrast media Study of the blood brain barrier in the rabbit following selective injection of contrast media into the internal carotid artery Acta radiol Diagnosis 10 (1970) 17

Jones C H Interpretation problems in thermography of the female breast Bibl radiol 5 (1969) 96

Krovetz L J Mitchell B M and Neumaster T Hemodynamic effects of rapidly injected hypertonic solutions into the heart and great vessels Amer Heart J 74 (1967) 453

Lawson R N and Gaston J P Temperature measurements of localized pathological processes Ann N Y Acad Sci 121 (1964) 90

Lindgren P Saltzman G F and Tornell G Vascular reaction to water soluble contrast media Significance of concentration and total amount of iodine Acta radiol Diagnosis 7 (1968) 152

Lundskog J Brånemark P I and Lindstrom J Biomicroscopic evaluation of microangiographic methods Advanc Microcirc 1 (1968) 152

Notter G und Melander O Thermographische Untersuchung bei Erkrankungen der Brustdruse Fortschr Rontgenstr 105 (1966) 657

Rosenberg N and Stefanides A Thermography in the management of varicose veins and venous insufficiency Ann N Y Acad Sci 121 (1964) 113

Saunders R L de C H and Montagna W X ray microscopy and microangiography Arch Dermat 89 (1964) 451

Skversky N J Herring A B and Baron R C Thermography in peripheral vascular diseases Ann N Y Acad Sci 121 (1964) 118

Strax P Thermography in mass screening for breast cancer Ann N Y Acad Sci 121 (1964) 282

Sorensen S E Changes in vascular permeability after local application of roentgen contrast media in the hamster cheek pouch Acta radiol Diagnosis 11 (1971) 274

— Local toxic effects of anaesthetics and *contrast media* in urethrography Acta radiol Diagnosis 12 (1972) 225

SUMMARY

The effects of roentgen contrast media and local anaesthetics locally applied to the tissue of the ear of the rabbit were investigated by macrophotography, thermography and microangiography. The tissue toxicity of each of the components of the drugs in addition to their combined action was examined. Some of the surface anaesthetics as well as some of the contrast media used in diagnostic radiology of the lower urinary tract and the female genital system were found to produce tissue changes.

ZUSAMMENFASSUNG

Die Wirkungen von Röntgenkontrastmitteln und Lokalanästhetica, die lokal auf das Gewebe des Ohrs des Kaninchens aufgebracht waren, wurden makrophotographisch, thermographisch und mikroangiographisch untersucht. Die Gewebstoxicität jeder der Komponenten dieser Mittel wurde untersucht. Einige der Oberflächenanästhetica ebenso wie einige der Kontrastmedia, die bei der Röntgendiagnostik der unteren Urinwege und dem weiblichen Genitalsystem verwendet werden, riefen Gewebsveränderungen hervor.

RÉSUMÉ

Les effects de moyens de contraste radiologique et d'anesthésiques locaux appliqués localement sur les tissus de l'oreille du lapin ont été étudiés par macrophotographie, par thermographie et par microangiographie. Les auteurs ont examiné la toxicité tissulaire de chacun des composants de ces agents. Certains anesthésiques de contact et certains des moyens de contraste utilisés pour la radiologie des voies urinaires inférieures et pour l'appareil génital féminin ont produit des lésions tissulaires.

REFERENCES

BELLMAN, S., ODEN, B. and VILANDER, E.: Microangiography. Bibl. anat. (Basel) (1961), 88.

BIRCH, J., BRÅNEMARK, P.-I. and LUNDSKOG, J.: The vascularization of a free full thickness skin graft. II. A microangiographic study. Scand. J. plast. reconstr. Surg. 3 (1969), 11.

— — and NILSSON, K.: The vascularization of free full thickness skin graft. An infrared thermographic study. Scand. J. plast. reconstr. Surg. 3 (1969), 18.

— — — and LUNDSKOG, J.: Vascular reactions in an experimental burn studied with infrared thermography and microangiography. Scand. J. plast. reconstr. Surg. 2 (1968), 97.

BOWLING BARNES, R. and GERSHON COHEN, J.: Clinical thermography. J. Amer. med. Ass. 185 (1963), 949.

BRÅNEMARK, P.-I.: Infrarodtermografi. Medicinsk användning av värmebildsteknik (In Swedish.) Spectrum International 2 (1965), 26.

— Intravital microscopy: its present status and its potentialities. Med. biol. Ill. 16 (1966), 100.

— Biologic and clinical evaluation of infrared thermography. J. Radiol. Electrol. 48 (1967), 69.

— and NILSSON, K.: Thermographic and microvascular studies of peripheral circulation. Medical thermography. Bibl. radiol. 5 (1969), 130.

— JACOBSSON, B. and SORENSEN, S. E.: Microvascular effects of topically applied contrast media. Acta radiol. Diagnosis 8 (1969), 547.

with the material of which it was made A higher incidence of thromboembolism occurred in coronary angiographies than when abdominal or peripheral angiography was performed Similarly SIEGELMAN et coll (1968) found that long large catheters and extended catheterization times predisposed to thromboses A high incidence of thrombosis also occurred at the site of the puncture in pull-out angiography

Pull out angiography was performed in 50 consecutive unselected patients of the present cardioangiography material in only two of these did small irregularities at the site of the puncture that indicated thrombosis appear

No systematic differences between the two groups of patients as to age distribution the substance of the catheter puncture technique, type of premedication or the amount of contrast medium were evident

One difference between the cardioangiography and the abdominal peripheral angiography groups however existed The exteriors and interiors of the catheters in the former were rinsed with heparin 5 000 IU/ml immediately before their insertion This procedure was not used in the peripheral angiographies and abdominal aortographies in which saline with the addition of 1 ml heparin per 1 000 ml saline was used The binding of heparin to the surface of prosthetic materials such as artificial aortic valves reduces the thrombus formation on the surface of such devices (GOTT 1966 and others) The extensive work of LAGERGREN et coll (1964 1969) has indicated that the treatment of surfaces of plastic materials with a tenside (bensalkon) followed by heparin results in a nonthrombogenic mono layer of heparin Similarly it may be assumed that the application of heparin to the inner and *outer surfaces* of the catheters used in the present cardioangiographies may to a certain extent have prevented the formation of thrombi since the catheters were sterilized by being kept in a 0 1 per cent solution of tenside for 24 hours before their use GLANCY et coll (1970) with two different coating *techniques* in animal experiments reported a significant decrease in the formation of thrombi on catheters coated with heparin compared with control catheters in the same animal

The effect of the simple application of heparin to the surfaces of the catheters would be expected to vary and to be only temporary some cases of thrombosis occur in spite of the use of heparin to the catheters The effect of coating the catheter with heparin is probably only local for the amount that will enter the circulation with this technique is minimal and would not change the general coagulation reaction The *method* may produce a high local concentration of heparin at the puncture site which could cause external bleeding the incidence of hematomas in the series was however no larger than in other series and no difference between the two groups of patients was evident

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HEPARIN COATING OF CATHETERS AGAINST THROMBOEMBOLISM IN PERCUTANEOUS CATHETERIZATION FOR ANGIOGRAPHY

by

I. BJÖRK

The percutaneous introduction of catheters is nowadays a routine measure in angiography. Thromboembolism leading to ischemia following this procedure is well recognized and occurs with a frequency of from 0.2 to 1.6 per cent in various materials (cf. ERIKSSON & JORULF 1969). A special heparin preparation of catheters for cardioangiography has been in use for approximately seven years at this centre.

An over-all complication frequency of 0.38 per cent (27 patients) was recorded in a total material of 7 166 consecutive cardioangiographies and thoracic aortographies, 0.18 per cent (13 patients) sequelae were due to thromboembolism. The frequency was 0.45 per cent (11 patients) in 2 461 consecutive abdominal and peripheral angiographies during the same period of time, with thromboembolism amounting to 0.28 per cent (7 patients). The extended catheterization time in the thoracic aortographies and cardioangiographies and the longer and larger catheters used in these examinations were not accompanied by a higher frequency of surgical thromboembolic sequelae. JACOBSSON & SCHLOSSMAN (1969), on the other hand, reported that the risk of thromboembolism following percutaneous catheterization of the femoral artery varied mainly with the length and size of the catheter and possibly also

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TOMOFLUOROSCOPY AND ITS APPLICATION IN THE EXAMINATION OF THE LUMBAR INTERVERTEBRAL JOINTS

by

SVEN REICHMANN

Tomofluoroscopy is a means of determining the most appropriate cut section level before tomography of a certain organ. Publications have emerged lately on this matter (CRYSLER 1970, FRIMANN DAHL & KUHL 1970). The input phosphor of an image intensifier was inserted at the film plane. The tomograph was then started and the cut section level changed until the organ to be tomographed remained stationary during the movement. The image intensifier was then withdrawn and tomography performed; a circular tomographic movement was recommended in both publications. No systematic investigation of the geometry or of the reliability of tomofluoroscopy was included in the investigations.

The equipments referred to seem to have certain disadvantages. CRYSLER mentions that the spheric form of the input phosphor of the image intensifier constitutes an obstacle. The tomographic plane is replaced by a tomographic surface of the same form as that of the input phosphor, although on a reduced

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Other measures to reduce the incidence of thromboembolism, such as pretreatment of the patients with 10 ml dextran 70 per kg body weight before the angiographic procedures, have been used by JACOBSSON (1969). Its administration by an intravenous drip is however relatively time consuming and the slight risk of infusing dextran must also be considered.

SUMMARY

The local application of heparin to the surface of bensalkon sterilized catheters in thoracic aortography and cardioangiography immediately before their insertion seemed to reduce the incidence of thromboembolic complications. The total material consisted of 7 166 patients.

ZUSAMMENFASSUNG

Es scheint, dass eine lokale Behandlung der bensalkonsterilisierten Katheter mit Heparin kurz vor deren Einführung das Entstehen von thrombo-embolischen Komplikationen bei der Aortographie oder Kardioangiographie vermindert. Ein Material von 7 166 Patienten wurde überprüft.

RÉSUMÉ

L'application locale d'héparine à la surface de cathéters stérilisés par le bensalkon pour l'aortographie thoracique et la cardioangiographie immédiatement avant leur introduction paraît réduire la fréquence des complications thromboemboliques. Cette méthode a été utilisée au total chez 7 166 patients.

REFERENCES

ERIKSSON I. and JORULF H.: Surgical complications associated with arterial catheterization. Scand. J. thorac. cardiovasc. Surg. 4 (1969), 69.

GLANCY J. J., FISHBONE G. and HEINZ E. R.: Nonthrombogenic arterial catheters. Amer. J. Roentgenol. 108 (1970), 716.

GOTT V.: The causes and prevention of thrombosis on prosthetic materials. J. surg. Res. 6 (1966), 274.

JACOBSSON B.: Effect of pretreatment with dextran 70 on platelet adhesiveness and thromboembolic complications following percutaneous arterial catheterization. Acta radiol. Diagnosis 8 (1969), 289.

— and SCHLOSSMAN D.: Thromboembolism of leg following percutaneous catheterization of femoral artery for angiography. Predisposing factors. Acta radiol. Diagnosis 8 (1969), 109.

LAGERGREN H., JOHANSSON L. und ERIKSSON C. H.: Die Einwirkung elektrisch geladener Flächen auf die Blutkoagulation. Thoraxchirurgie 12 (1964), 172.

— — —: Medicinska och tekniska användningar av tensidbehandlade plastytor. (In Swedish.) Report to the Swedish Technical Research Council 1969.

SIEGELMAN S., CAPLAN L. and ANNER G.: Complications of catheter angiography. Study with oscillometry 'pullout' angiograms. Radiology 91 (1968), 251.

during the whole sequence of tomofluoroscopy The reason for this is the ability of the photographic film to store the information practically independently of time The information obtained at the beginning of the sequence is thus integrated with the information obtained at the end The process is the same as occurs directly when tomography in film is performed

All this may be summarized as follows The recording in television tomofluoroscopy consists of a series of images each having properties of an ordinary roentgenogram No blurring occurs in tomofluoroscopy but sharp contours appear on the TV screen with different states of movement The same contours move in the same way over the film in tomography but here the movement is not evident in the final tomogram The movement however contributes to the tomographic blurring (REICHMANN 1972 b) Tomofluoro copy is not always so simple that a distinction may be made between moving and motionless contours ince a contour may be stationary only during part of the total tomofluoroscopic sequence The reason for this is the fact that the movement of a contour is influenced partly by the form of the corresponding ab orption boundary as will be described later Different types of absorption boundary will be investigated in order to see how their corresponding contours move on the TV screen during tomofluoroscopy

Geometric aspects This part of the analysis consists of a description of the principles illustrated in Figs 1 to 6 Certain conditions are always present (cf Fig 1) The tomographic movement path is linear and from certain points — usually three — of this path roentgen rays to the absorption boundary have been indicated Three tomographic planes are drawn and may be assumed to correspond to three possible levels pre ent on different occa ions of tomofluoroscopy It is difficult to analy e how the ab orption boundary is *projected* onto the moving input phosphor of the image intensifier during the whole equence of the procedure This information may however be more easily obtained if the method in which the absorption boundary is *projected* onto the corresponding tomographic plane is examined The tomographic plane is stationary and has a constant projection onto the *input phospor* during the whole equence of tomofluoroscopy the projection onto the tomographic plane is thus the same as that onto the input phosphor It is assumed in this connec tion that the input phosphor of the image intensifier is plane and ituated at the film level The correcting procedures necessary when these prerequisites cannot be fulfilled will be dealt with below

Tomofluoroscopy of a cylindric ab orption boundary appears in Fig 1 An in pection of the uppermost tomographic plane (To P I) reveals that the roentgen beam which depicts the cylinder *surface* is moving from left to right over the tomographic plane during the exposure in other words the cylinder

scale, in tomofluoroscopy with a spheric input phosphor Only a small central part of the fluoroscopic screen may therefore be used Another drawback is the fact that apparatus of the type described by the above mentioned authors is not commercially available today

Tomofluoroscopy may be performed with two standard fluoroscopic units, however, and a systematic test of the usefulness of one of these will be presented First, however, a theoretic analysis of the geometric principles inherent in the tomofluoroscopic performance will be described since this at times may be more complicated than generally believed

Theoretic analysis

General aspects and definition of terms Tomography in this analysis refers to the process in which the information inherent in roentgen radiation is recorded in a roentgen film The term tomofluoroscopy implies a process in which information is recorded fluoroscopically instead of photographically For the sake of simplicity the movement of the tomograph will be called tomographic movement even in tomofluoroscopy, a distinction between 'tomofluoroscopy' and 'tomography' being made only when the process of recording is discussed

Every contour in the image in tomography as in ordinary radiography corresponds to where tissues of different absorption properties for roentgen rays meet The surface where this meeting of differently absorbing tissues takes place is termed an 'absorption boundary'

If tomofluoroscopy is performed by means of a television unit, which is the only realistic alternative at present, the single tomogram is replaced by a long series of consecutive images, as in cineradiology Since one tomographic movement in tomofluoroscopy is recorded in the form of a large number of different television images, contours from absorption boundaries outside the tomographic plane cannot be expected to be blurred in each of the single TV images as in the single tomogram in film Each TV image will instead have roughly the properties of a conventional roentgenogram and the appearances of the tomofluoroscopic sequence on the TV screen will be one of low unsharpness of all contours, even where the corresponding absorption boundaries are situated far from the tomographic plane The relation between a given absorption boundary and the latter is thus not reflected in the degree of blurring but in the direction and velocity of the movements of the corresponding contour over the TV screen Only when all the partial images of the tomofluoroscopic television sequence are copied onto each other, and thus integrated into one image, will the characteristic blurring of tomography occur Such a copying may be obtained if a photographic camera depicts the TV screen with the shutter open

during the whole sequence of tomofluoroscopy The reason for this is the ability of the photographic film to store the information practically independently of time The information obtained at the beginning of the sequence is thus integrated with the information obtained at the end The process is the same as occurs directly when tomography in film is performed

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Geometric aspects This part of the analysis consists of a description of the principles illustrated in Figs 1 to 6 Certain conditions are always present (cf Fig 1) The tomographic movement path is linear and from certain points — usually three — of this path roentgen rays to the absorption boundary have been indicated Three tomographic planes are drawn and may be assumed to correspond to three possible levels present on different occasions of *tomofluoroscopy* It is difficult to analyse how the absorption boundary is projected onto the moving input phosphor of the image intensifier during the whole sequence of the procedure This information may however be more easily obtained if the method in which the absorption boundary is projected onto the corresponding tomographic plane is examined The tomographic plane is stationary and has a constant projection onto the input phospor during the whole sequence of tomofluoroscopy the projection onto the tomographic plane is thus the same as that onto the input phosphor It is assumed in this connection that the input phosphor of the image intensifier is plane and situated at the film level The correcting procedures necessary when these prerequisites cannot be fulfilled will be dealt with below

Tomofluoroscopy of a cylindric absorption boundary appears in Fig 1 An inspection of the uppermost tomographic plane (*To P I*) reveals that the roentgen beam which depicts the cylinder surface is moving from left to right over the tomographic plane during the exposure in other words the cylinder

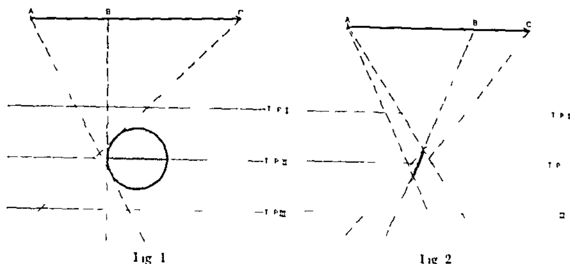


Fig 1 Tomofluoroscopy of a horizontal cylinder by means of linear tomographic movement from A to C Three possible tomographic planes (To P I II and III) are indicated The projection of the cylinder surface onto these planes occurs when the focus is at three different positions of its movement path

Fig 2 Tomofluoroscopy of a plane absorption boundary by means of linear tomographic movement Same conditions as in fig 1

surface seems to move on the TV screen in the direction of the focus movement The same thing will occur in the lowest tomographic plane (To P III) but the direction of movement will be the opposite Thus, when the tomographic plane is situated above the cylinder, its image wanders over the screen in the direction of the focus movement, when the tomographic plane is below the cylinder this occurs in the opposite direction

Special circumstances are present when the tomographic plane passes through the cylinder in such a way that true tomographic depiction is possible as in tomographic plane II (Fig 1) When the focus moves from A to B the projection of the cylinder surface onto the tomographic plane moves in the direction of the focus movement, when the focus proceeds from B to C the cylinder projection moves in the opposite direction The roentgen beam strikes the cylinder surface tangentially in the tomographic plane when the focus is at B This means that if tomography with film be performed the contour of the cylinder surface is formed at that particular moment This may be accepted as true, as it is only when the focus is at B and the direction of movement is changed that the projection of the cylinder surface remains stationary in relation to the tomographic plane

The TV screen will record the following events as the tomographic plane passes through the cylinder The image of the cylinder moves in the direction

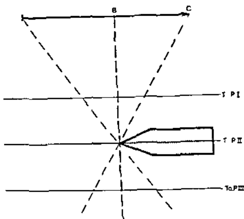


Fig 3 Tomofluoroscopy of an edge shaped absorption boundary by means of linear tomographic movement Same conditions as in fig 1

of the focus movement, then stops for a moment before returning in the opposite direction The contour in the tomogram recorded in film is formed when the direction of movement is changed It is therefore possible to judge if the tomographic plane passes through the axis of the cylinder or if it is eccentrically situated In the former ca e the change of direction occurs in the middle of the tomographic movement in the latter it occurs early or late during the move ment

Tomofluoroscopy of a plane ab orption boundary is analysed in Fig 2 Three tomographic planes (Fig 1) are again indicated as are the roentgen beams from three different focus po itions The ab orption boundary can now only be depicted from one focus position namely the one labelled B in Fig 2 A contour corresponding to the absorption boundary in question will appear on the TV screen only during part of the tomographic movement Analogously with the considerations of the cylindric absorption boundary the following may be stated If the tomographic plane is situated above the ab orption boundary the contour moves with the focus during that period when it appears as a harp contour on the TV screen If the tomographic plane lies below the absorption boundary the direction of movement is the opposite If the contour is stationary and appears harp then the plane passes through the ab orption boundary

Some absorption boundaries especially in the skeleton have the form of a more or less harp edge the depiction of such boundaries is presented in Fig 3 The image moves in the same way in the tomographic planes outside the edge as described above However when the tomographic plane passes through the edge a contour remains stationary during the whole tomographic movement

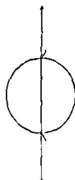


Fig. 4. Tomofluoroscopy of a spherical absorption boundary by means of linear tomographic movement. The sphere as well as the movement path of the focus viewed from above. The arrows indicate those parts of the spherical surface that move in the same way as the surface of a horizontal cylinder (cf. fig. 1).

Tomofluoroscopy of spherical absorption boundaries may be performed by means of linear tomographic movement (Fig. 4). The sphere and the tomographic movement path are viewed from above. If those parts of the sphere perpendicular to the movement path are inspected (arrows, Fig. 4), the same conditions will be present as in tomofluoroscopy of a horizontal cylinder (Fig. 1). In fact the same type of movement on the TV screen will be evident if other parts of the contour be inspected, but the magnitude of the movement will decrease when the inspection point is moving laterally. The most lateral points of the sphere will reveal that the absorption boundary is parallel with the tomographic movement path. Such a parallelism in tomography gives rise only to spurious contours (REICHMANN 1972 a), and likewise no information can be obtained from these inspection points; optimal information is thus gained only when the points indicated by arrows are examined.

Tomofluoroscopy of slanted cylindric absorption boundaries has been analyzed (Figs. 5, 6). The linear movement path in Fig. 5 moves at right angles to a *vertical plane through the axis of the cylinder and the central roentgen ray* sweeps over an elliptic figure (Fig. 5 b). The tomofluoroscopic image corresponding to this central roentgen ray would have moved in essentially the same way as if the cylinder had been horizontal. The roentgen rays on both sides of the central ray in Fig. 5 a are also sweeping over elliptic figures, even if the form of the ellipse varies. Every part of the cylinder is thus represented in the same manner as the part struck by the central ray. However, there is one important exception. The different parts of the cylinder all have their own relations to the tomographic plane which modifies the movement scheme of the contours. When a cylindric absorption boundary is observed tomofluoroscopically as in Fig. 5, the cylinder is depicted as in Fig. 5 c. The principal projection of the slanted cylinder onto a horizontal plane, such as the input phosphor of the imagined image intensifier, is apparent; three zones will be

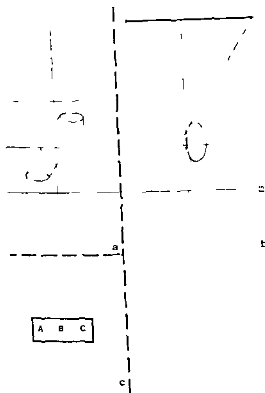


Fig 5 Tomofluoroscopy of a slanted cylinder by means of linear tomographic movement a) The cylinder and the movement path of the focus The latter is perpendicular to the image plane the central roentgen ray is marked by an interrupted vertical line b) This ray sweeps over the surface of the cylinder during the tomographic movement The projection in (b) is perpendicular to the projection in (a) and the whole tomographic movement path is visible Only that part of the cylinder surface immediately below the movement path appears in (b) This surface has the form of an ellipse and its tomofluoroscopic depiction is that of a horizontal cylinder (cf fig 1) c) The image of the cylinder in the TV screen has three zones of different movements

tomofluoroscopically visible The contours in zone A will move in the direction of the tomographic movement during the whole of the movement since the corresponding parts of the cylinder are situated below the tomographic plane The opposite movement will occur in zone C The contours in zone B will change their direction of movement this does not happen all at once but early at one end of the zone and late at its other end

A slanted cylinder may at times be examined tomofluoroscopically (Fig 6) The linear tomographic movement path is in a vertical plane that passes along the axis of the cylinder The inspection is concentrated on those parts of the cylinder surface marked by arrows in Fig 6 b where the cylinder is viewed from above These surface parts will be tomofluoroscopically depicted in the same manner as a plane absorption boundary (Fig 6 a)

Tomofluoroscopy may be performed by means of multidirectional tomographic movements These have not been considered since the geometry of tomofluoroscopy is then complicated to such a degree as sometimes to become

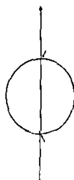


Fig 4 Tomofluoroscopy of a spherical absorption boundary by means of linear tomographic movement The sphere as well as the movement path of the focus viewed from above The arrows indicate those parts of the spherical surface that move in the same way as the surface of a horizontal cylinder (cf fig 1)

Tomofluoroscopy of spherical absorption boundaries may be performed by means of linear tomographic movement (Fig 4) The sphere and the tomographic movement path are viewed from above If those parts of the sphere perpendicular to the movement path are inspected (arrows, Fig 4), the same conditions will be present as in tomofluoroscopy of a horizontal cylinder (Fig 1) In fact the same type of movement on the TV screen will be evident if other parts of the contour be inspected, but the magnitude of the movement will decrease when the inspection point is moving laterally The most lateral points of the sphere will reveal that the absorption boundary is parallel with the tomographic movement path Such a parallelism in tomography gives rise only to spurious contours (REICHMANN 1972 a), and likewise no information can be obtained from these inspection points, optimal information is thus gained only when the points indicated by arrows are examined

Tomofluoroscopy of slanted cylindric absorption boundaries has been analysed (Figs 5, 6) The linear movement path in Fig 5 moves at right angles to a vertical plane through the axis of the cylinder and the central roentgen ray sweeps over an elliptic figure (Fig 5 b) The tomofluoroscopic image corresponding to this central roentgen ray would have moved in essentially the same way as if the cylinder had been horizontal The roentgen rays on both sides of the central ray in Fig 5 a are also sweeping over elliptic figures, even if the form of the ellipse varies Every part of the cylinder is thus represented in the same manner as the part struck by the central ray However there is one important exception The different parts of the cylinder all have their own relations to the tomographic plane which modifies the movement scheme of the contours When a cylindric absorption boundary is observed tomofluoroscopically as in Fig 5, the cylinder is depicted as in Fig 5 c The principal projection of the slanted cylinder onto a horizontal plane, such as *the input* phosphor of the imagined image intensifier, is apparent, three zones will be

in the geometric analysis are certainly blurred in tomofluoroscopy with a long lag time as well as in tomography on film However the analysis has also disclosed that most of the sharp contours of the film tomogram are formed only during a short moment of the total exposure time, namely when the contour is halted in the corresponding tomographic plane this moment being too short for a slow reacting TV camera to build up a contour Practical test with a slow reacting Vidicon camera confirmed this analysis when the procedures to be described were attempted The final result was that no sharp contours at all were evident on the TV screen The lag time must thus be so short that each single image in the sequence of TV images does not contain a significant amount of information from the previous or later images For this reason rapid reaction TV cameras such as those of the Plumbicon type, are the only possible ones for use in tomofluoroscopy

The Polytome (Massiot Paris) can be equipped with a 6′ image intensifier and a TV camera This television unit is marketed by the manufacturer only for the adjustment of the view field size and not for tomofluoroscopy The image intensifier is attached to the Bucky unit in such a way that the input phosphor is situated some centimetres under the film plane and cannot be lifted up to that plane The image intensifier and TV camera move together with the Bucky unit The unit can thus participate in the tomographic movement but the input phosphor is situated outside the film plane and is curved

The other roentgen unit that is easily adapted for tomofluoroscopy is the Coordinate Combi Table with a Pendulum Stand for linear tomography (Elema Schonander Stockholm) Strictly speaking this is not a tomograph but has the geometric properties of the Danatome (EDHOLM 1960) Only relatively small tomographic angles can be used so that its function does not deviate appreciably from that of true tomographs This roentgen unit will for the sake of simplicity be regarded in the following as a tomograph The moving component apart from the focus is not the film but the patient so that a stationary image intensifier may thus participate in the tomographic procedure The tomograph is usually equipped with a 9′ image intensifier standing on the floor The input phospor does not coincide with the film plane it is curved and so the same adapting problems arise for this unit as for the Polytome

The adaptation necessary for both tomographs was achieved by means of a system of small roentgen visible markers evenly spaced and fastened to the surface of a masonite board The markers were placed in the film plane A board of appropriate thickness could thus be substituted for a cassette in the Polytome The cassette holder was withdrawn and the board with markers placed on top of the image intensifier and adjusted to the level of the film plane in the Coordinate Combi Table

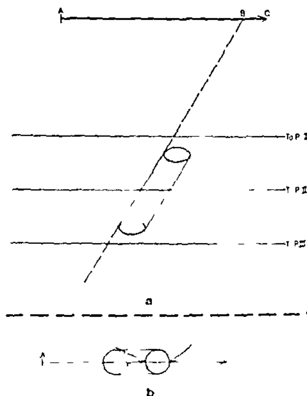


Fig 6 Tomofluoroscopy of a slanted cylinder by means of linear tomographic movement The movement path travels at right angles to that of fig 5 i e in a plane along the axis of the cylinder a) The cylinder is viewed from the side and b) perpendicularly from above Those parts of the cylinder surface indicated by arrows in (b) present the same conditions as in tomofluoroscopy of a plane absorption boundary (cf fig 2)

impossible An exception is tomofluoroscopy with small tomographic angles and a circular movement, which will be mentioned later

Tests were carried out with two types of standard roentgen machine

Practical aspects

Technical considerations Tomofluoroscopy necessitates the tomograph being equipped with a television unit that can participate in the movement In this connection one important prerequisite for fluoroscopy should be considered TV cameras may differ as regards time lag A camera with a long time lag does not stop image production immediately when the current of the roentgen tube is switched off and the image persists for some time as afterglow Such a camera can store information for a while and if this afterglow had a sufficient intensity and duration, it might seem possible to store and integrate the whole tomofluoroscopic sequence into a stationary tomogram, just as happens in tomography on a film with its excellent storing and integrating capacity It would then be unnecessary to follow the movement of different contours since the stationary tomogram would appear on the TV screen However this is not possible since if the lag time be long it takes about the same time to build up a contour as it takes to make it vanish Contours that have been found to move

in the geometric analysis are certainly blurred in tomofluoroscopy with a long lag time as well as in tomography on film However, the analysis has also disclosed that most of the sharp contours of the film tomogram are formed only during a short moment of the total exposure time namely when the contour is halted in the corresponding tomographic plane, this moment being too short for a slow reacting TV camera to build up a contour Practical test with a slow reacting Vidicon camera confirmed this analysis when the procedures to be described were attempted The final result was that no sharp contours at all were evident on the TV screen The lag time must thus be so short that each single image in the sequence of TV images does not contain a significant amount of information from the previous or later images For this reason rapid reaction TV cameras such as those of the Plumbicon type are the only possible ones for use in tomofluoroscopy

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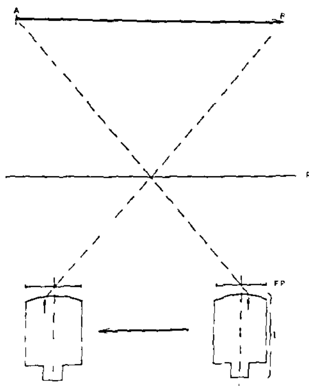


Fig 7 Tomofluoroscopy with the input phosphor below the film plane (F P) The central roentgen ray from focus positions A and B passes through the central points in the tomographic plane (To P) and the film plane It strikes the curved input phosphor of the image intensifier (I I) at the side of its centre at a point marked by an arrow this point moves during the examination

A system of dark points on the TV screen corresponded to the markers A distortion of the relative position of the markers occurred in both types of TV unit owing to the curvature of the input phosphor All points moved on the screen when the tomographic movement was started because the input phosphor lay under the film plane (Fig 7) The curvature of the input phosphor gave rise to a difference in movement between points at the centre and those at the periphery of the screen, the latter moving more rapidly Tomofluoroscopy enabled a comparison of the contours of the object to be made with the movement of the reference points, so that contours which were motionless in the film plane were seen to move together with the adjacent reference points

Practical tests Tomofluoroscopy was performed with at horizontal cylinder (8 cm diameter), a plane absorption boundary (height 1 cm) and a sharp edge, with both the tomographs The objects were made of aluminium for maximum contrast The movement was linear, with the tomographic plane in the position of Figs 1 to 3, the tomofluoroscopic image moving in accordance with theory

The routine examination of the lumbar intervertebral joints was investigated with the Polytome REICHMANN (1972 c) recommends that these joints should be tomographed without previous routine roentgen examination, tomography thus

becoming not the last resort but the main approach The mall size of the joints made the choice of the cut section level somewhat difficult

The joint surfaces of the lumbar intervertebral joints are roughly cylindric and tomofluoroscopy could thus be performed according to the principles outlined in Fig 1 The material consisted of five excised lumbar spines The joints were free from obvious changes (REICHMANN 1972 c) The first two ca es were examined without any oft tissue phantom and the last three cases after addition of 15 cm paraffin wax substituting the soft tissue The tomofluoro copy was performed at 60 kV, with no oft tissue with the phantom inserted the potential had to be raised to 110 kV, with the Bucky grid in tomofluoro copy as well as in tomography Tomography was performed when the level of the tomographic plane was considered to be suitable Onlv one tomogram was taken in the first case in which the precision of the tomofluoroscopy proved insufficientlv high In the four other cases three tomograms were obtained One was taken directly after the tomofluoroscopy the other two being obtained after raising or lowering of the tomographic plane by 5 mm The tomographic movement was hypocycloid with an angle of 48 Kodak RP film was u ed in combination with Ilford Standard intensifying screens

Tomofluoroscopy when first attempted was considered difficult with the Polytome linear movement since this extends over 1 5 s at a tomographic angle of 60 The angular velocity thus became high, and its lowering was considered justified in the initial stage low velocity was employed in the tomofluoro copy of the first ca e the lowering being achieved by means of a reduction in the tomographic angle However this could only be obtained for the circular movement The first case was therefore examined tomofluoroscopically with a circular movement with 18 tomographic angle All movements on the creen became slow but on the other hand they had to be differentiated into a component at right angles to the contour and one parallel with the contour The last mentioned component afforded no useful information Linear tomofluoroscopy was therefore considered preferable when all relevant types of contour motion could be distinguished on the screen However it was felt that tomofluoroscopy with small tomographic angles and a circular movement may be justified when the image contrast on the screen is very low the extremely low angular velocity of the Coordinate Combi unit produced excellent tomofluoroscopy

The examinations of the 4 ca es by the Polytome and linear tomofluoroscopy with three tomograms after each centering proved to be satisfactory It was not always the intermediate tomographic plane that gave the best result but one of the other tomograms was usually acceptable Sixteen centerings were made and only in 2 of the e was it necessary to take one complementary tomogram after the inspection of the first three One of the successful series appears in Fig 8



Fig. 8. A lumbar intervertebral joint with a soft tissue phantom tomographed after tomofluoroscopic centering of the tomographic plane. The tomographic plane chosen appears in (b). The planes in (a) and (c) lay 5 mm on each side of the plane in (b).

Discussion

Tomofluoroscopy is possible with two tomographs after minimal adjustments. The fact that some initial training is needed is no argument against the method, initiation being necessary in all types of skilled fluoroscopic examinations. The procedure described is thus possible to perform today with an acceptable degree of accuracy. As regards the Polytome and the objects tested, the lumbar intervertebral joints, it is advisable to obtain three tomograms at different levels after each centering since the accuracy of the tomofluoroscopic centering seems to approach ± 5 mm. It is reasonable to assume that this scheme is also useful in tomography of other organs; if zonography be performed one exposure should often suffice although the need for tomofluoroscopy in zonography is limited.

Rapid development of technical apparatus may be expected in the field of tomofluoroscopy. Justification appears therefore to exist for discussing the future improvement of certain factors, such as the form and movement of the input phosphor, the electronic integration of the moving image to a definite tomogram on the TV screen, and the use of tape recorders to reduce the radiation hazard.

Units for roentgen television with a plane input phosphor are not in common use today (WALLMAN 1971) although units have been constructed in which the input phosphor is separated from the photo cathode of the image intensifier

(SCHOTT 1964) The light is brought from the input phosphor to the photo-cathode by means of a system of mirrors and len es It has al o been suggested (WALLMAN 1971) that fibre optics may be u ed for this purpose Thus although the photo-cathode has to be curved it is possible to obtain an image intensifier with a plane input phosphor, with such a unit it eems desirable to make the input pho phor move in the same direction as the film If this demand be fulfilled the same tomographic plane will appear in the monitor as in the tomogram on film The implest way to obtain this similarity of movement is by locating the input pho phor in the film plane The practical con equence is however, that the image intensifier has to be removed when film tomography is to be performed The input phosphor may however be situated under the film plane if only its movement is o much faster than that of the film that the central roentgen ray always trikes the midpoint of the input pho phor (cf Fig 7) This effect is achieved in the Polytome if the image intensifier be attached directly to the vertical parallelogram on to which the tube and the Bucky unit are attached The level of the attachment in the parallelogram shuld be the same as that of the plane input phosphor

The u e of a tape recorder in combination with electronic integration has been described by DUMMLING (1969) The sequence of events during one complete tomographic movement is stored on video tape from which the sequences may be repeatedly projected in the monitor The interesting point is that by means of electronic guiding of the monitor apart from that provided by the tape recorder a change in the cut section level may be imitated The condition is however that the input phosphor is plane DUMMLING compared this induced change in the cut section level with the depiction of different tomographic planes in multi ection tomography which al o produces many planes at one exposure A considerable do e reduction would be possible in tomofluoroscopy with this unit DUMMLING al o de cribed how the integration of the moving image into a stationary tomogram may be performed electronically The combination of this integrating unit with the tape recorder unit in fact makes it possible to obtain stationary tomograms on the TV creen at any cut section level after only one tomographic exposure This combined unit will however necessarily be expensive its cost exceeding by many times that of the tomograph itself The video tape unit seems to be valuable for two rea ons First the do e reduction mentioned above and econdly the possibility of demonstrating the tomo-fluoroscopic sequence in slow motion and thus simplifying the procedure the present investigation has however indicated that the electronic integrating unit is not necessary for precision tomofluoroscopy It may be replaced by a much cheaper Polaroid camera in front of the TV screen for those rare occasions when an integration of the image seems desirable

Acknowledgement

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SUMMARY

Tomofluoroscopy is a method of selecting an appropriate cut section level in tomography The movement of organs of different forms on the screen during tomofluoroscopy with a TV system with an acceptably short time lag is described Two different tomographs together with their standard units for TV fluoroscopy may easily be adapted for the procedure

ZUSAMMENFASSUNG

Die Tomofluoroskopie ist eine Methode um ein geeignetes Schnittniveau bei der Tomographie auszuwählen Die Bewegung von Organen verschiedener Form auf dem Schirm während der Tomofluoroskopie mit einem TV System mit einer annehmbaren kurzen Zeitverzögerung wird beschrieben Zwei verschiedene Tomographieapparate zusammen mit deren Standardeinheiten für TV Fluoroskopie können ohne Schwierigkeit für dieses Verfahren verwendet werden

RÉSUMÉ

La tomoradioscopie est une méthode pour choisir le niveau approprié de la couche de coupe en tomographie L auteur décrit le mouvement d organes de formes différentes sur l écran au cours de la tomoradioscopie au moyen d un système de télévision ayant un retard de temps de brièveté acceptable Deux tomographes différents équipés de leur appareillage standard de radioscopie télévisée peuvent être facilement adaptés pour cette technique

REFERENCES

CRYSLER W E Tomoscopy and related matters Amer J Roentgenol 109 (1970) 619
DÜMMLING K Ein neues Verfahren zum Mehrfachschichten mit Hilfe von Fernschbildsp eichern Radiologe 9 (1969) 37
EDHOLM P The tomogram Its formation and content Acta radiol (1960) Suppl No 193
FRIMANN DAHL J and KUHL H B Immediate centering and tomographic cut localization by means of roentgen television Acta radiol Diagnosis 10 (1970) 236
REICHMANN S (a) Development of spurious contours of spherical and cylindrical objects in tomography Acta radiol Diagnosis 12 (1972) 317
— (b) Modified theory of the development of tomographic blurring Acta radiol Diagnosis 12 (1972), 457
— (c) Tomography of the lumbar intervertebral joints Acta radiol Diagnosis 12 (1972) 641
SCHOTT O Rontgenfernsehen Rontgenpraxis 17 (1964) 2
WALLMAN H Personal communication (1971)

FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF H LODIN), AND RADIOPHYSICS (DIRECTOR J CEDERLUND) AKADEMISKA SJUKHUSET AND THE DEPARTMENT OF RADIOBIOLOGY (DIRECTOR PROF B LARSSON) THE GUSTAF WERNER INSTITUTE UNIVERSITY OF UPPSALA SWEDEN

SOFT TISSUE INTENSIFICATION IN FRONTAL ROENTGENOGRAPHY OF THE LARYNX

by

ANDERS HEMMINGSSON BO JUNG and HANS LUNDQVIST

The perception of roentgenographic detail is not completely understood but may well be dependent upon the radiation absorption gradient over the contour of a projected structure (WALLS 1954) and its inference by other structures TUDDENHAM 1957 EDHOLM 1960)

The visibility of the soft tissue structure is disturbed and limited by the spongy bone of the cervical vertebrae in frontal roentgenography of the larynx Structures of low contrast are thus masked by the closely spaced structures of fairly high contrast Laryngography is the best *method* of improving the visibility of laryngeal soft tissue (POWERS et coll 1957 THORNBURY & LATOURETTE 1967 BRINDLE 1966 LANDMAN 1970 HEMMINGSSON 1972 and others) This technique necessitates premedication and anaesthesia with the contrast media used at present other techniques with a similar diagnostic accuracy but without this disadvantage are therefore desirable

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The reproduction of laryngeal soft tissue structures should be characterized by low spatial frequencies and that of spongy bone by comparatively high frequencies. It should thus be possible to improve soft tissue detail and to reduce the disturbance of spongy bone by a change in one or more of the modulation transfer functions (ROSSMANN 1963, 1964). Changes can be made in the variables starting with the focus diameter of the roentgen tube (LUBBERTS & ROSSMANN 1967) and ending with the distance at which the final image is viewed (TUDDENHAM 1957, 1963). Frequency filtration of images may precede the latter (SCHOTT 1967, LEDHOLM & QUIDING 1970, and others).

Possible techniques. An increased tube potential reduces the contrast of spongy bone more than that of soft tissue (STEPHANI 1929, BEQUE & ROTENBERG 1965, MAGUIRE et coll. 1965, MAGUIRE 1966, THORNBURY & LATOURETTE 1967, HEMMINGSSON & LUNDQVIST 1972). The subtraction technique (e.g. VIGNAUD PASQUIER et coll. 1963) eliminates the reproduction of spongy bone provided that two roentgenograms with equivalent positions of bone structures are obtained, the soft tissue structures to be examined must have non-equivalent positions or be of different contrast relative to bone in the two films.

Tomography reduces the reproduction of structures lying outside the larynx. This method has proved inaccurate, however (HEMMINGSSON 1972), and will not be discussed further.

A deliberate increase in the degree of geometric unsharpness will reduce the high frequency components in the image leaving those of low frequency comparatively unaffected. This effect was utilized by LINDGREN (1939) by means of a p.a. projection and a short distance between the focus and the vertebrae as well as between the larynx and the film. Unsharpness due to finite focus dimensions blurs the image of the spongy bone in the vertebra while laryngeal detail, lying closer to the recording layer, is less affected. An increased viewing distance or the use of diminishing viewing glasses (TUDDENHAM 1957, 1963) produces an effect similar to increased geometric unsharpness.

Modern frequency filtration (SCHOTT 1967, LEDHOLM & QUIDING 1970, and others) is probably perfectly capable of producing improvement in the rendering of the soft tissue over that of interfering bone. This could be easily affected in one dimension by applying, for example, computer or video methods while good two dimensional processing may necessitate an advanced analogue technique such as holography, for example, in order to be practical.

Methods. The influence of different tube potentials was investigated by means of a cervical phantom (HEMMINGSSON 1971) with frontal projections at 50 and 200 kV. Rods of Mix D with diameters of 2, 3, 4 and 5 mm were placed in the 'laryngeal cavity' of the phantom in some of the exposures. The inherent filtration of the tube was 1.8 mm Al, no extra filtration was added at the lower potential

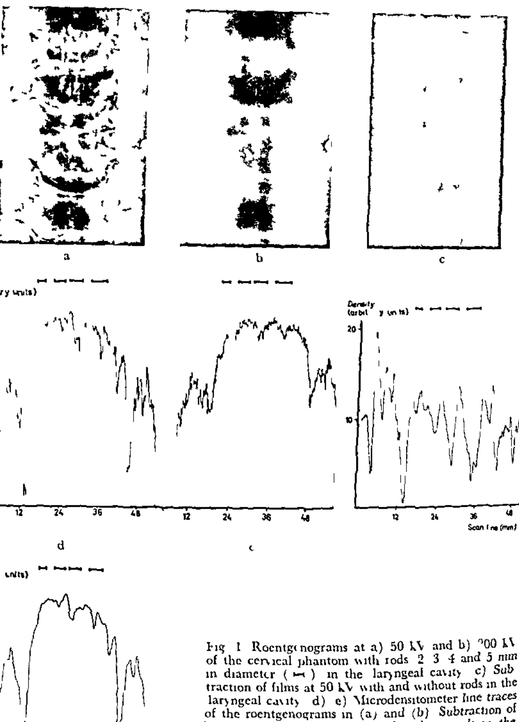


Fig. 1. Roentgenograms at a) 50 kV and b) 200 kV of the cervical phantom with rods 2, 3, 4 and 5 mm in diameter (⊢) in the laryngeal cavity. c) Subtraction of films at 50 kV with and without rods in the laryngeal cavity. d) e) Microdensitometer line traces of the roentgenograms in (a) and (b). Subtraction of

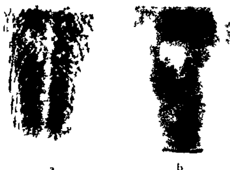


Fig 2 A dried femur with a 10 mm pellet of soft tissue equivalent material (Mix D) on the surface towards the film Focus film distance 120 cm pellet film distance 10 cm a) Film and screens in intimate contact and b) at 1 mm distances

of amplitudes in the microdensitometer trace caused by bone and by soft tissue (i e the rods of known dimensions in the laryngeal cavity of the phantom) This relationship was determined for 50 and for 200 kV

The line spread function $LS(x)$ for different distance (h) between the film and the screen was fixed as $LS(x) = h/(x + h)$ and the corresponding modulation transfer functions were calculated

Results

The rods in the laryngeal cavity of the phantom could just be observed in the film obtained at 200 kV but not in that at 50 kV (Fig 1 a b) The microdensitometer traces of these roentgenograms disclose fluctuations due to spongy bone that are smaller at 200 kV than at 50 kV (Fig 1 d e)

The photographic subtraction of the 50 kV roentgenograms with and without rods in the laryngeal cavity yields an image in which the rods are easily perceived (Fig 1 c) The density fluctuations due to the bone structures are partially eliminated also in the difference curve between the microdensitometer traces from the films with and without rods in the laryngeal cavity (Fig 1 f) The elimination is not perfect since the traces were not obtained on exactly equivalent lines

The two-dimensional filtration obtained with increased geometric unsharpness is illustrated in Fig 2 The 10 mm pellet in the sharp roentgenogram is perceived only as a faint ill defined object in the spongy bone (Fig 2 a) while in the film with increased unsharpness (Fig 2 b) its contour is evident The effect of increased unsharpness was mainly due to the spacing of screens and film The perception of the rods in the laryngeal cavity of the cervical phantom was also enhanced in the films with marked unsharpness

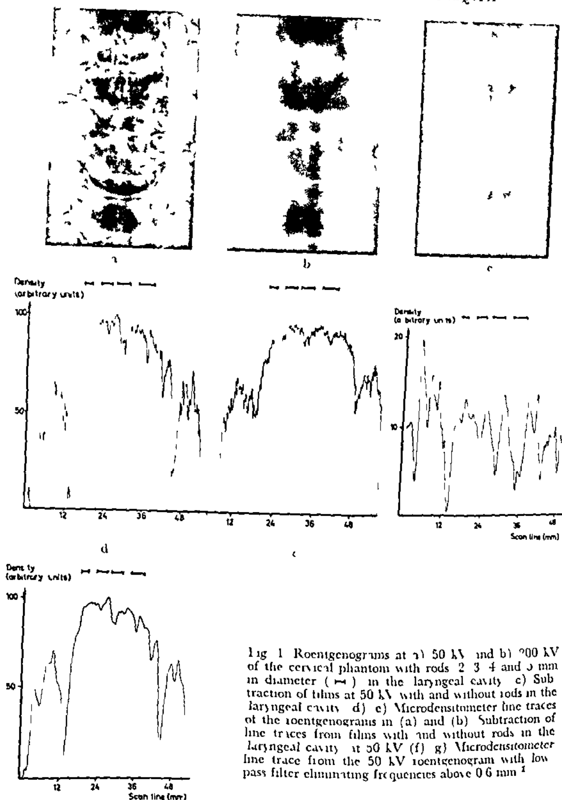


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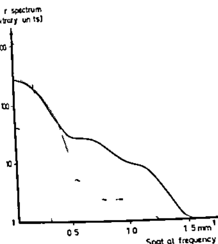


Fig 4 Power spectra of roentgenograms of the cervical phantom without rods in the laryngeal cavity and calculated spectra of spherical soft tissue structures. The amplitudes of the spectra demonstrate the relation between soft tissue and bone at different potentials ——— soft tissue structure 4 mm in diameter soft tissue structure 2 mm in diameter ——— cervical phantom 50 kV and — — — cervical phantom 200 kV

The power spectra of the roentgenograms of the cervical phantom without rods in the laryngeal cavity appear in Fig 4 as well as the spectra calculated for rounded soft tissue structures with diameters of 2 mm and 4 mm. The spectra of the cervical phantom have the same general shape at 50 and 200 kV but the amplitude is considerably lower at the higher potential. These spectra are mainly due to the cervical spine in the phantom as the remainder except for the laryngeal cavity was homogeneous. The calculated spectra of the spherical soft tissue structures — appropriately related to the spectra of the phantom at 50 and 200 kV — indicate that the structures would be more obvious at the higher potential.

Discussion

The microdensitometer line trace is more irregular at 200 kV than at 50 kV (Fig 1 d e) probably due to increased quantum mottle at the higher potential. The amplitude of the small variations in photographic density due to spongy bone is lower at the higher potential (Fig 1 d e). This explains why the rods are easier to observe at 200 kV than at 50 kV and illustrates quantitatively the effect of a high potential technique.

Photographic subtraction is a suitable method of eliminating masking by spongy bone in a roentgenogram (Fig 1 c). It demands however that the films are obtained with the bone structures at exactly equivalent positions and with an altered position of the soft tissue structures; this could not be achieved in practice (HEMMINGSSON 1971). If two frontal films of the larynx were obtained

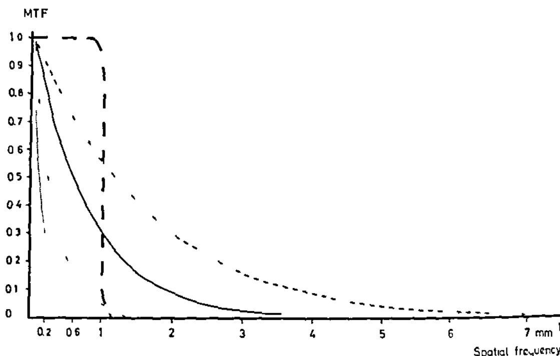


Fig. 3. Modulation transfer functions calculated for different distances between the screens and the film and a low pass filter eliminating frequencies above 1.0 mm^{-1}. Distance between intensifying screen and film emulsion — — — 0.1 mm ——— 0.2 mm 0.5 mm 1 mm — — low pass filter.

Defocussing of the sharp roentgenogram in a TV chain and with diffusing yielded similar results as the increased geometric unsharpness described.

The pellet is easier to perceive at a viewing distance of about 2 m than at shorter distances in the roentgenogram reproduced in Fig. 2a.

The modulation transfer function for the plastic foil system is given in Fig. 3. The function for a distance of 0.1 mm between the screens and the film corresponds closely to that obtained by ROSSMANN (1963, 1964), for an ordinary, medium speed film screen system. The functions for distances of 0.5 and 1 mm are considerably lower at all frequencies and do not conserve the low frequency components adequately.

The low pass filter illustrated in Fig. 3 would be much better in this respect, the effect of such a filter, eliminating frequencies above 0.6 mm^{-1} on the micro densitometer trace of the 50 kV roentgenogram, is demonstrated in Fig. 1g. The density differences due to the 3, 4 and 5 mm rods are clearly enhanced over the fluctuations due to spongy bone. Low pass filters with higher and lower cut off frequencies gave poorer results.

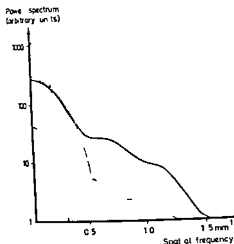


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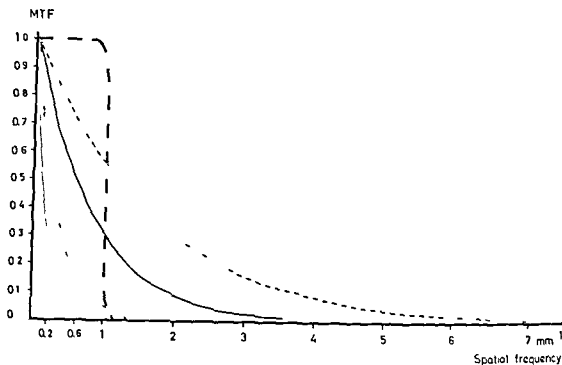


Fig. 3. Modulation transfer functions calculated for different distances between the screens and the film and a low pass filter eliminating frequencies above 1.0 mm^{-1}. Distance between intensifying screen and film emulsion — — — 0.1 mm —— 0.2 mm 0.5 mm 1 mm — — low pass filter

Defocussing of the sharp roentgenogram in a TV chain and with diffusing yielded similar results as the increased geometric unsharpness described.

The pellet is easier to perceive at a viewing distance of about 2 m than at shorter distances in the roentgenogram reproduced in Fig. 2 a.

The modulation transfer function for the plastic foil system is given in Fig. 3. The function for a distance of 0.1 mm between the screens and the film corresponds closely to that obtained by ROSSMANN (1963, 1964), for an ordinary, medium speed film screen system. The functions for distances of 0.5 and 1 mm are considerably lower at all frequencies and do not conserve the low frequency components adequately.

The low pass filter illustrated in Fig. 3 would be much better in this respect, the effect of such a filter, eliminating frequencies above 0.6 mm^{-1} on the micro densitometer trace of the 50 kV roentgenogram, is demonstrated in Fig. 1 g. The density differences due to the 3, 4 and 5 mm rods are clearly enhanced over the fluctuations due to spongy bone. Low pass filters with higher and lower cut off frequencies gave poorer results.

The effect of the low pass filter in Fig 1 g indicates that the representation of the soft tissue structures will not be affected appreciably by an adequate low pass filter Such a one-dimensional type of filtration would be possible with video techniques (EDHOLM & QUIDING 1970) while two-dimensional filtration is much more complicated

The contour of the pellet is partly visible when the viewing distance is increased to about 2 m (Fig 2) This is due to two-dimensional filtration of the roentgenogram performed by the human eye brain system The modulation transfer function for the human eye is given in Fig 5 (from ORHALG 1971) The long viewing distance (2 m) eliminates frequencies above 0 8 mm¹ This effect also explains why diminishing glasses proved to be more effective than ordinary viewing for detection of metastases in the lung (TUDDENHAM 1963) This technique will however always produce a poorer result than an appropriate low pass filtration

Conclusion

A high potential technique makes soft tissue structures easier to perceive in the presence of spongy bone diminishing the contrast of the latter The contrast of the soft tissue structures is also reduced though to a smaller degree

The subtraction technique is theoretically ideal for eliminating the image of spongy bone It requires however an altered position or different contrast of the soft tissue to be examined

The frontal representation of an anatomic cervical phantom contains frequencies up to 1 5 mm¹ Soft tissue structure with diameters above 2 mm lie in the low frequency part of this spectrum while the high frequency part is due mainly to spongy bone and radiographic motile An unsharpness or unsharpened reproduction of a roentgenogram increases the perception of soft tissues by suppressing the high frequency part of the spectrum due to spongy bone The modulation transfer functions for the defocusing processes that have been investigated are unsatisfactory however since they also affect the low frequency part of the spectrum

An increased viewing distance yields two-dimensional band pass filtration produced by the human eye brain system The perception of soft tissue will thus be increased to approximately the same degree as with increased geometric unsharpness

Low pass filters with a suitable cut-off frequency improve the visibility of soft tissue in a cervical phantom This technique performed in a closed circuit TV system will increase the diagnostic accuracy of such tissue when spongy bone lies in the beam It is also applicable in for example gas myelography

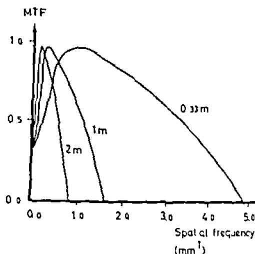


Fig. 5. The modulation transfer function for the human eye-brain system at viewing distances of 0.33, 1.0 and 2.0 m. (Modified from OHI[illegible] 1971.)

with identical spatial relationships at different tube potentials — which might be easier to achieve in practice — photographic subtraction would enhance the largest contrast difference, i.e. the representation of the bone structures (ZIEDSES DES PLANTES 1961). If, however, the amplitudes of the bone images were equilibrated, by for example video techniques, the image of soft tissue structures would remain. Photographic techniques give adequate subtraction of the bone image in such a case (LIDHOLM, personal communication 1971).

The representation of laryngeal soft tissue should contain dominantly low frequencies, a 2 mm structure having a cut off at 0.6 mm^{-1} (Fig. 4). The high frequency part of this spectrum will be reduced further if the penumbral effects are taken into account. Spongy bone produces images with a considerable component at higher frequencies (ROCKOFF 1967, HEMMINGSSON & LUNDQVIST 1972). Roentgenographic mottle contains still higher frequencies (ROSSMANN 1963). The latter two components can thus be suppressed by low pass frequency filters. The simple technique of two dimensional filtration attained by increased geometric unsharpness is often adequate. The contour of the soft tissue structure is thus perceptible in Fig. 2 only in the defocussed image; the technique introduced by LINDGREN (1939) is also based upon this effect. The modulation transfer function is however reduced for all frequencies in the roentgenogram. A distance of 1 mm between the screens and the film seemed to give the best results in the present case. This distance is accompanied by an approximately ten fold decrease in the modulation transfer function at all frequencies compared with an ordinary film screen system. Similar results were obtained by ROSSMANN (1963). A much better effect on the image should therefore be expected with an appropriate low pass filter (Fig. 3).

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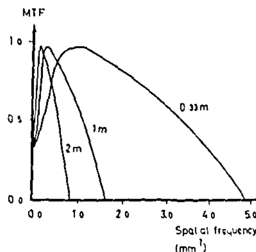


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HEMMINGSSON A. Cervical phantom for evaluation of different methods of roentgen examination of the larynx. Acta radiol Diagnosis 11 (1971) 515
— Roentgenologic examination of the larynx. A clinical comparison. Acta radiol Diagnosis 12 (1972) 433
— and LUNDQVIST H Optimum photon energy in ordinary radiography of the larynx Acta radiol Diagnosis 12 (1972) 305
LANDMAN G H M Laryngography and cinelaryngograhy Excerpta Medica Foundation Amsterdam 1970
LINDGREN E Über die Rontgenuntersuchung des Larynx. Fortschr Rontgenstr 59 (1939) 273
LUBBERTS G and ROSSMANN K. Modulation transfer function associated with geometrical unsharpness in medical radiography Phys. in Med Biol. 12 (1967) 65
MAGUIRE G H The larynx Simplified radiological examination using heavy filtration and high voltage Radiology 87 (1966) 102
— BEIQUE R A. and ROTENBERG A. D Selective filtration The practical approach to high kilovoltage radiography Radiology 85 (1965) 343
ORHAUG T Bilder bildinformation bildbearbetning (In Swedish.) FOA 2 report A 2538—51 FOA Repro Stockholm 1971
POWERS W E MC GEE H H and SEAMAN W B Contrast examination of the larynx and pharynx. Radiology 68 (1957) 169
ROCKOFF S D Radiographic trabecular quantitation of human lumbar vertebrae in situ I Theory and method for study of osteoporosis Invest Radiol 2 (1967) 272
ROSSMAN K Spatial fluctuations of X ray quanta and the recording of radiographic mottle Amer J Roentgeol 40 (1963) 863
— Some physical factors affecting image quality in medical radiography J Photogr Sci 12 (1964) 279
— Measurement of the modulation transfer function of radiographic systems containing fluorescent screens Phys in Med Biol. 9 (1964) 551
SCHOTT O Elektronische Informationsaufbereitung in der Rontgendiagnostik. Elektromedizin 12 (1967) 1
STEPHANI J De l emploi de l antidiffuseur pour les radiographies pulmonaires J Radiol. Électrol 13 (1929) 393
THORNBURY J R and LATOURETTE H B A comparison study of laryngography techniques. Amer J Roentgenol 99 (1967) 555
TUDDENHAM W J The visual physiology of roentgen diagnosis Amer J Roentgenol. 78 (1957) 116
— Problems of perception in chest roentgenology Facts and fallacies Radiol. Clin. N Amer 1 1963 277
VIGNAUD-PASQUIER J DANIC J et SUDAKA J La méthode de soustraction Application a la radiographie en O R L. Rev Laryng (Bordeaux) (1963) Suppl No 865
WALLS G L The filling in process Amer J Optom. 31 (1954) 329
ZIEDSES DES PLANTES B G Subtraktion Georg Thieme Stuttgart 1961

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Acknowledgements

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SUMMARY

Low pass filtration eliminating frequencies above 0 6 mm⁻¹ appears to be a useful tech que *for suppressing the image of the* spongy bone of the cervical spine without affecting soft tissue in frontal roentgenograms of the larynx Other methods including high tential and subtraction techniques are also discussed

ZUSAMMENFASSUNG

Starke Filtrierung die Frequenzen hoher als 0 6 mm⁻¹ eliminiert scheint eine anwend re Technik um die Anwesenheit des spongiosen Knochens der Halswirbelsaule ausza halten ohne das Weich Gewebe in frontalen Aufnahmen des Larynx zu beeinflussen Andere thoden einschliesslich der mit hohen Spannungen und der Subtraktionstechnik werden enfalls diskutiert

RÉSUMÉ

La filtration passe bas eliminant les frequences de plus de 0 6 mm⁻¹ parait etre une *hnique* propre pour supprimer l image de l o spongieux de la colonne cervicale sans difier l image des tissus mous sur les cliches de face du larynx Les autres methodes y mpris les techniques de haute tension et les techniques de soustraction sont aussi étu es

REFERENCES

INGER E O ANNE A and MC DONALD D A Use of Fourier series for the analysis of biological systems Biophys J 6 (1966) 291

QUE K A and ROTENBERG A D Effect of filtration in diagnostic radiology J Canad Ass Radiol 16 (1965) 59

NDLE M J Radiology of the larynx Thesis University of Liverpool 1966

RNSWEET T N Visual perception Academic Press New York 1970 Cited by Othaug (1971)

HOLM P The tomogram Its formation and content Acta radiol (1960) Suppl No 193 Personal communication (1971)

and QUIDING L Elimination of blur in linear tomography Acta radiol Diagnosis 10 (1970), 441

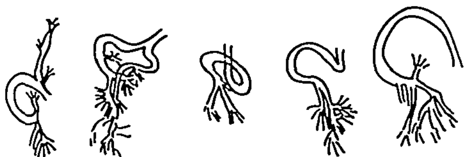


Fig 1 Various types of ventral primary branches True lateral view (Ventral direction to the left)

this concept the primary branches of the main renal artery are generally called the dorsal and ventral branches Confusion arises with the second set of branches as no standard nomenclature has been adopted BOIJSEN used the terms secondary or segmental arteries while the anatomists CASTELLI & HUELKE (1969) called them the interlobar branches The next set of branches were termed *subsegmental by BOIJSEN and primary arcuate arteries* by CASTELLI & HUELKE The terminal branches are universally called the interlobular' arteries

Experiences gained from three dimensional elective angiography has cast some doubts on the relevance of some of these classical reports Whether it is correct to classify the branches of the renal artery as ventral and dorsal arteries or to adhere to any of the standard anatomic schemes regarding the size and intrarenal localization of the arterial segments has therefore been investigated Since a nomenclature should be accurate the main branches of the renal artery have in the present investigation been called the primary branches the next the secondary branches and the following division the tertiary branches The term interlobar artery has as by BOIJSEN been reserved for the arterial branch that lies in a column of Bertin and gives off arcuate arteries Interlobar' is thus synonymous with the interpyramidal or intermedullary

Method HEGEDUS (1972) in an earlier communication described a technique for the angiographic appreciation of the renal shape and volume in three dimensions. The lateral projection of the kidney together with the conventional a p projection has been used in the present investigations. The line between the areas of supply of the primary branches of the renal artery lies mainly at the sagittal plane of the kidney and is best represented in the lateral projection The combination of the lateral and a.p projections produces in addition a three dimensional representation of the arterial distribution in relation to the cortex medulla sinus and pelvis.

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF O OLSSON),
UNIVERSITY HOSPITAL, LUND, SWEDEN

ARTERIAL ANATOMY OF THE KIDNEY

A three dimensional angiographic investigation

by

V HEGEDUS

The literature on the arterial anatomy of the kidney is extensive HUNTER (1794) stated that no inter-arterial anastomoses arose in the kidney HYRTL (1872) suggested that the dorsal and ventral halves of the kidney were completely separate entities as regards their arterial supply BRODEL (1900) described the anatomy of the renal arteries for surgical purposes and GREGOIRE (1906) and MORISON (1926) discussed the renal circulation The embryology and topography of the kidney, especially of the pyramids were investigated in detail by FELIX (1906), FUCHS (1925), HOU JENSEN (1930) and LOFGREN (1949) GRAVES (1954 1956) and SMITHUIS (1956) demonstrated the segmental arterial anatomy in specimens of cadaver kidneys Anatomic investigations have continued to the present time, the most recent being by POISEL & SPANGLER (1970) An important contribution to the roentgenologic anatomy was by BOIJSEN (1959) on the segmental distribution of the renal arteries based upon LOFGREN's investigation of the topography of the pyramids With minor differences in details these authors all followed the general principle that the two main arterial areas of supply were distributed ventro dorsally Because of

Submitted for publication 26 April 1971



Fig 4 Arterial distribution in two right and three left kidneys true lateral Well delineated demarcation between the areas of supply of the arteries indicates various types of arterial distribution

nal analysis in the present series has given some insight into the tortuous course of this artery The course between the aorta and the hilum of the kidney was direct in 38 8 per cent of the patients while in the remaining patients it sometimes ran a markedly tortuous course The course and tortuosity were symmetric in 16 (50 per cent) of the 32 bilateral examinations

The primary and secondary branches and their areas of supply Two primary branches were evident in 70 8 per cent of the kidneys three primary branches in 20 8 per cent and four branches in 8 4 per cent One of the primary branches passed dorsally to the renal pelvis in 40 patients (33 3 per cent) Some secondary branches coursed dorsally to the renal pelvis in 18 patients (15 per cent) In 12 patients (10 per cent) the relation of the branches to the renal pelvis could not be established because of the absence of contrast medium in the pelvis. The primary branch that ran ventrally to the renal pelvis produced an accentuated ventral convexity in 23 patients (19 2 per cent) (Fig 1) and in only one patient could a slight dorsal convexity be demonstrated A similar situation in which a dorsal primary branch produced a dorsally oriented arch was present in only 5 patients The cranial and caudal branches of the ventral secondary arteries have a different topography the caudal branches being more arched

The usual appearance of the intrarenal arteries in the lateral projection is demonstrated in Fig 2 in which sharp demarcation between the ventral and dorsal areas of supply of the primary branches is evident Another type of branching of the primary artery appears in Fig 3 a branching into cranial and caudal areas of supply Many variations between these two extremes exist The



Fig 2



Fig 3a



Fig 3b

Fig 2 True lateral view Arterial phase Distinct boundary between areas of supply by the primary branches indicated by white line

Fig 3 Tip of catheter directed towards one of the primary branches The difference in filling indicates boundary between the areas of supply which in this case are cranio caudal a) Ap b) True lateral

Material This consisted of kidneys with a normal arterial anatomy and included 120 kidneys supplied by one artery and 50 kidneys fed by two or three arteries Most patients had pathologic changes on the contralateral side Thirty two in whom no abnormality was evident at bilateral selective angiography had cystitis, possible glomerulonephritis, strain haematuria, cancerophobia and slight albuminuria The material consisted of 71 male and 67 female patients (86 right kidneys and 84 left kidneys), the ages ranged from 12 to 79 years

Results

Kidneys with one artery

The main renal artery The origin, extrarenal course and branching of the main renal artery have been described by HELLSTROM (1928), HOU JENSEN (1930), MELKONIAN (1954) BOIJSEN (1959), inter alios The three dimensio

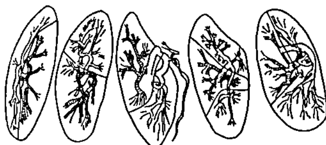


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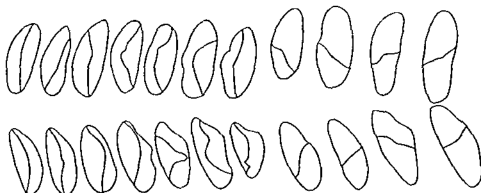


Fig 6 *Left* Arterial distribution in true lateral projection in 7 right kidneys (upper row) and 7 left kidneys (lower row) with two primary branches Longitudinal supply boundaries between the two primary branches *Right* Example of transverse division of 4 right kidneys (upper row) and 4 left kidneys (lower row)

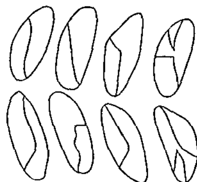


Fig 7 Arterial supply of 4 right kidneys (upper row) and 4 left kidneys (lower row) in true lateral projection illustrating intermediate types of boundaries of areas of supply

areas of supply may be outlined in the true lateral view (Fig 4) by the three dimensional technique which provides enough general information However fine detail of these frequently irregular zones of supply may be depicted in three dimensional drawings utilizing at least two projections (Fig 5) The 120 examinations have been analyzed by drawing the e areas in the lateral projection as described with the following results

Eighty five kidneys with two primary branches (1) The plane dividing the areas of supply was mainly longitudinal indicating a ventro-dorsal distribution of supply in 41 kidneys (48 per cent) (Fig 6 left) (2) The plane dividing the areas of supply was mainly transversely oriented, indicating a cranio caudal division of the zones of supply in 36 kidneys (42 per cent) (Fig 6 right)

a

b

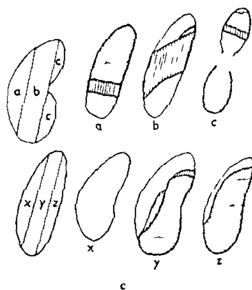


Fig. 5. Right kidney. a) A-p. b) True lateral. Unusual ventrally convex arch of the cranio-ventral secondary branch. c) Areas of supply revealed in detail in zones sketched by transferring information from the one projection to the other. The white fields and the horizontally hatched fields indicate the areas of supply of the two primary branches. The vertically hatched fields represent areas supplied by both primary branches.



Fig 10 a) b) Selective investigation of primary arteries with separate origins in kidney of Group I True lateral Irregular supply boundaries c) Electronic colour subtraction of (a) and (b) indicates the mutual relation of the two supply areas

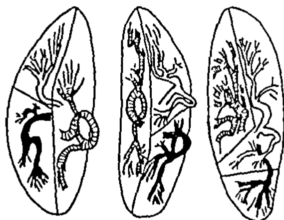


Fig. 8. Boundaries of arterial supply in kidneys with 3 primary branches in true lateral projection. Primary branches indicated.

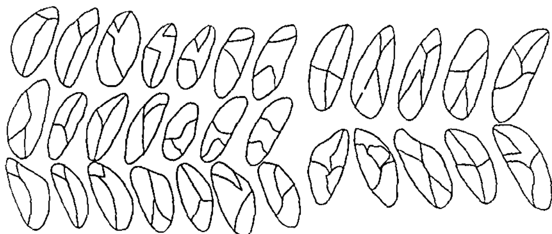


Fig. 9. Boundaries between the areas of arterial supply in 21 kidneys with 3 primary branches (left) and in 10 kidneys with 4 primary branches (right). True lateral projection.

(3) The remaining eight kidneys (10 per cent) were of intermediate types (Fig. 7).

Twenty five kidneys were supplied by three, and 10 kidneys by four primary branches, their arterial supply was analyzed by the same method. The variations in this fairly small series were considerable and it is not possible to classify them into informative groups. An arterial topography similar to that in kidneys with two primary branches was usually evident (Figs. 8, 9).

Kidneys with multiple arteries

Fifty kidneys were supplied by more than one main artery, 47 of these being fed by two arteries and 3 by three arteries, with separate origins from the aorta



Fig 11 (For legend see opposite page)



Fig 12 (For legend see opposite page)

Fig. 11. a) Selective investigation of main artery in a kidney of Group II. True lateral. b) Aortography. Supplementary artery (⟷) supplies the entire pars inferior of the kidney and parts of the pars intermedia dorsally and represents a secondary branch; the first branch of the main artery (⟶) has also the appearance characteristic of a secondary branch

Fig. 12. a) Selective investigation of the main artery in a kidney of Group III. True lateral. b) Aortography. The lower lip of the hilum and the dorsal half of the pars inferior are supplied by the supplementary artery



Fig. 13 a) Selective investigation of a kidney of Group IV True lateral Small unfilled area dorsally (—) b) Aortography Supplementary artery with the appearance of an interlobar artery (—→)

artery in one kidney supplied the cranial pole and the ventral intermediate part of that kidney

Group III contained supplemental arteries to the lower pole in 11 kidneys and to the upper pole in 2 kidneys Six of the lower pole arteries supplied only the dorsal part of the pole and the lower margin of the hilum and another five the medio-dorsal part of the pole In one kidney the lower pole artery supplied the pole both ventrally and dorsally Only two kidneys had a supplemental artery to the ventro-lateral part of the pole (Figs 12 14) The two upper pole arteries in this group supplied parts of the upper hilar margin and an upper ventro-lateral part of the kidney respectively

The supplemental artery in Group IV was very small The areas of supplemental supply were the tip of the lower pole a small area in the intermediate part ventro-laterally and an area medio dorsally near the upper pole, respectively (Figs 13 14)

This material included three kidneys with three renal arteries, as previously stated The areas of supply in this small sample appear at random The two larger arteries in two of the kidneys were mainly ventro dorsally oriented, the smallest artery in these kidneys supplied an upper latero ventral area and a medio-dorsal area near the upper hilar margin, respectively In the third kidney the largest artery supplied both the dorso ventral intermediate parts of the kidney one small artery running to each pole the upper artery fed the upper pole ventrally and the other the lower pole medio-dorsally (Figs 15, 16)

The arterial distribution in kidneys supplied by multiple arteries is thus so unpredictable that an informative classification of the size and intrarenal localization of the arterial segments is not possible

The different arteries were usually examined selectively in a.p. and true lateral projections; when selective angiography failed, the remaining arteries were demonstrated by aortography. Nine of the 47 kidneys with two main arteries had both arteries selectively examined in both projections. Fifteen of these 47 kidneys had both arteries selectively examined but one of the arteries was examined only in the a.p. projection; in the remaining 23 kidneys one artery was examined selectively in both projections and a.p. aortography performed. The three kidneys supplied by three arteries were examined in a.p. and true lateral projections by selective injections of two of the arteries, followed by aortography; the third artery was also selectively catheterized at one examination.

The incidence of multiple renal arteries, site of aortic origin and the extra-renal course have been reported in the roentgenologic literature by EDSMAN (1957) and BOIJSEN (1959); the present material adds little new to these reports, which will therefore not be reviewed.

The relative significance of the arteries and a three-dimensional consideration of their areas of supply

The areas of supply of the primary branches in kidneys fed by a single renal artery may be described as mainly ventro-dorsal, cranio-caudal or of an intermediate type. When a classification of kidneys with multiple renal arteries was attempted, it was found that it had to be one based on the relative significance of each artery in the renal vascularity. The following groups then emerged:

I. The two arteries behaved like two primary branches (14 kidneys).

II. The larger of the arteries acted as a main renal artery with primary branches, while the smaller replaced a secondary branch (14 kidneys).

III. The larger of the arteries represented a main artery supplied with all the primary and secondary branches. The smaller renal artery replaced a tertiary branch which divided into a few interlobar arteries (16 kidneys).

IV. The larger artery supplied the whole kidney with the exception of the supply from one interlobar artery which had a separate aortic origin (3 kidneys).

The area of arterial supply in Group I in four kidneys could be divided ventro-dorsally and in nine kidneys cranio-caudally. The border in one kidney was of an intermediate type (Figs. 10, 14).

The smaller artery in Group II supplied a part of the lower pole in 13 of the 14 kidneys. In eight of these 13 kidneys the ventral intermediate part of the kidney as well as the most distal part of the lower pole were supplied by the smaller artery; in 5 of these 13 kidneys the smaller artery fed the intermediate part of the kidney dorso-medially as well as the lower pole (Figs. 11, 14). The



Fig 15 (For legend see opposite page)

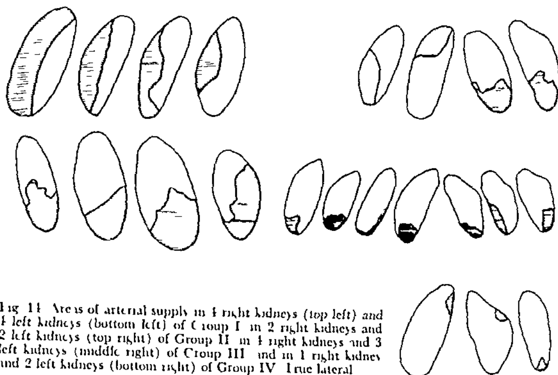


Fig. 14. Areas of arterial supply in 4 right kidneys (*top left*) and 4 left kidneys (*bottom left*) of Group I, in 2 right kidneys and 2 left kidneys (*top right*) of Group II, in 4 right kidneys and 3 left kidneys (*middle right*) of Group III, and in 1 right kidney and 2 left kidneys (*bottom right*) of Group IV. True lateral.

Discussion

No estimation of the tortuosity of the course of the main renal arteries is possible without a three-dimensional approach. The often surprisingly marked tortuosity of the primary branches and their relationship to the renal pelvis will otherwise not be demonstrable. In approximately a fifth of the kidneys examined the ventro-caudal branch formed an arch of ventral convexity.

Modern urologic surgery has created a demand for the preoperative demonstration of the areas of supply of the individual arteries. HYRTL (1872) described the kidney divided dorso-ventrally. MORISON (1926) demonstrated that the branches of the renal arteries were end-arteries. PALUMBO (1952) observed in specimens that there was no avascular zone present between the areas of supply.

GRAVES (1954) constructed models of the arterial supply of kidneys in ca-

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Fig. 15. a), b) Ap. Two primary branches with separate origins from the aorta catheterized selectively. c) Superimposition of (a) and (b) by IV subtraction and harmonization. A small cortical unfilled area lies latero-ventrally (→) demonstrated to better advantage in a true lateral projection (d).



Fig 15 (For legend see opposite page)



Fig. 16. The unfilled area in fig. 15 is supplied by one small artery catheterized together with the arteries to the adrenal gland with the appearance of an interlobar artery

davers and proposed a scheme of segmental distribution based on the appearance of the secondary branches. DI DIO (1961) inter alios obtained the same results. SYKES (1964) tried to correlate the results obtained by GRAVES with the lobulation of the kidney surface. BOIJSEN described four arterial segments, GRAVES five, LEVIN (1963) six, FALLER & UNGVÁRY (1962) seven independent arterial segments of the kidney. Finally POISEL & SPÄNGLER (1970) declared that a strict division of the kidneys into arterial segments is not giving a true picture of the actual conditions. The present author fails to agree with the above-mentioned authors on the number of segments in a kidney.

One of the advantages of examining kidneys in a true lateral projection is that the borders of the different areas of supply may be demonstrated with a high degree of accuracy as demonstrated by BOIJSEN (1959) in autopsy investigations. The areas supplied by the primary branches may be drawn directly on the films with but little error. Less than half the kidneys supplied by only one artery are divided ventro-dorsally, in 42 per cent of these it is more correct to speak of the division being cranio-caudal.

The smaller artery in kidneys with multiple arteries may supply a part varying in size from nearly half a kidney down to only a small area. It is thus obvious that a new definition of the renal arterial segment is necessary.

SUMMARY

By using a lateral projection of the kidney in addition to the in nephroangiography commonly used views a more detailed information of the arterial supply was obtained. This method may be of value in investigations before surgical intervention.

ZUSAMMENFASSUNG

Durch Anwendung einer lateralen Projektion der Niere zusätzlich zu den bei der Nephroangiographie gewöhnlich verwendeten Bildern wurde eine mehr detaillierte Information über die arterielle Versorgung erhalten. Diese Methode mag bei Untersuchungen vor einem chirurgischen Eingriff von Wert sein.

RÉSUMÉ

Avec une incidence de profil du rein supplémentaire à des vues habituelles en angiographie rénale on obtient plus de renseignements sur l'apport artériel. Cette méthode peut être utile dans les examens qui précèdent une intervention chirurgicale.

REFERENCES

BOIJSEN E. Angiographic studies of the anatomy of single and multiple renal arteries. Acta radiol. (1959) Suppl. No. 183.

BRÖDEL M. The intrinsic blood vessels of the kidney and their significance in nephrotomy. Bull. Johns Hopk. Hosp. 12 (1900) 10.

CASTELLI W. A. and HUELKE D. F. Intrarenal vascular distribution in human kidney. J. Urol. 102 (1969) 12.

DI DIO L. J. A. The anatomo-surgical vascular segments of the human kidney. Anat. Res. 139 (1961) 299.

EDSMAN G. An ionephrography and suprarenal angiography. Acta radiol. (1957) Suppl. No. 155.

ENEIN A. A. A. A. The segmental anatomy of the kidney and its relation to the intrarenal vascular and pyramidal systems. Alexandria med. J. 9 (1963) 66.

EN ELBRECHT H. E., KEEN E. N., FINE H. et coll. The radiological anatomy of the parenchymal distribution of the renal artery. S. Afr. med. J. (1969) 826.

FALLER J. and UNGVARY G. Die arterielle Segmentation der Niere. Zbl. Chir. 87 (1962) 972.

FELIX W. Die Entwicklung des Harnapparates. Handbuch des Entwicklungslehre der Wirbeltiere. O. Hertwig 1906.

FUCHS F. Untersuchungen über die innere Topographie der Niere. Z. urol. Chir. 18 (1925) 164.

GRAVES F. T. The anatomy of the intrarenal arteries and its application to segmental resection of the kidney. Brit. J. Surg. 42 (1954) 132.

— The anatomy of the intrarenal arteries in health and disease. Brit. J. Surg. 43 (1956) 605.

— The renal circulation. Med. Press 236 (1956) 455.

— The aberrant renal artery. J. Anat. 90 (1956) 553.

GRÉGOIRE R. Circulation artérielle et veineuse du rein. Bull. Soc. anat. Paris 8 (1906) 193.

HEGEDÜS V. Three-dimensional estimation of renal shape and volume at angiography. Acta radiol. Diagnosis 12 (1972) 87.

HEIDSIECK, E.: Zur Skeletotopie der grossen Äste der Bauchaorta. Anat. Anz. 66 (1928) 6.
HELLSTRÖM, J.: Über die Varianten der Nierengefässe. Z. urol. Chir. 24 (1928) 253.
HELM, F.: Zur Topographie der menschlichen Niere. Anat. Anz. 11 (1896) 97.
HOU-JENSEN, H.: Die Verästelung der Arteria renalis in der Niere des Menschen. Z. Anat. Entwickl.-Gesch. 91 (1930) 1.
HUNTER, J.: Inflammation and gun-shot wounds. C. Nicol, London 1794.
HYRTL, J.: Das Nierenbecken der Säugetiere und des Menschen. Denkschr. Kaiserl. Akad. Wissensch. Math.-Naturwissensch. Cl. 31 (1872) 107.
KOHLER, R.: Incomplete angiogram in selective renal angiography. Acta radiol. Diagnosis 1 (1963) 1011.
LAGERGREN, C. and LJUNGQUIST, A.: The intrarenal arterial pattern in chronic pyelonephritis. Virchows Arch. path. Anat. 335 (1962) 584.
LJUNGQUIST, A. and LAGERGREN, C.: Normal intrarenal arterial pattern in adult and ageing human kidney. J. Anat. 96 (1962) 285.
LÖFGREN, F.: Das topographische System der Malpighischen Pyramiden der Menschenniere. AB Gleerupska Universitetsbokhandeln, Lund 1949.
MC DONALD, D. F. and KENELLY, JR. J. M.: Intrarenal distribution of multiple renal arteries. J. Urol. 81 (1959) 25.
MELIKONIAN, L.: Systémisation de 14 cas d'anomalie des artères rénales. Acta med. iugosl. 8 (1954) 257.
MORISON, D. M.: A study of the renal circulation with special reference to its finer distribution. Amer. J. Anat. 37 (1926) 53.
OLSSON, O. (in collaboration with JONSSON, G.): Roentgen examination of the kidney and ureter. In: Encyclopedia of urology. Springer Verlag, Heidelberg 1962.
PALUMBO, V.: Studio anatomo-radiologico sul compartimento dell'arteria renale sull'uomo in relazione specialmente alla nefro-angiografia e alla chirurgia conservatrice del rene. (In Italian.) Arch. ital. Urol. 25 (1952) 329.
POISEL, S. und SPÄNGLER, H. P.: Über aberrante und accessorische Nieren-Arterien bei Nieren in typischer Lage. Anat. Anz. 124 (1969) 244.
— —: Die Verästelungstypen der Arteria renalis im Hinblick auf die arterielle Blutversorgung des Parenchyms der Niere. Ein Beitrag zum Problem der sogenannten Nierensegmente. Acta anat. 76 (1970) 516.
RAUBER, A. und KOPSCH, F.: Lehrbuch und Atlas der Anatomie des Menschen. 16. Aufl. Vol. 2. p. 465. G. Thieme Verlag, Leipzig 1941.
SMITHUIS, T.: The problem of renal segmentation in connection with the modes of ramification of the renal artery and the renal vein. Arch. chir. neerl. 8 (1956) 227.
SCHNEIDER, E., ISKE, C. und SCHNEIDER, W.: Zahl, Abstand der Verzweigungsstellen vom Rand des Sinus renalis und Kaliber der extrarenalen Nierengefässe des Menschen. Anat. Anz. 124 (1969) 278.
SYKES, D.: The correlation between renal vascularization and lobulation of the kidney. Brit. J. Urol. 36 (1964) 549.
ZONDEK, M.: Beitrag zu den Gefahren der Nephrotomie. Bruns Beitr. klin. Chir. 79 (1912) 716.

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TRANSLUMBAR AORTOGRAPHY WITH TEFLON CATHETERS

by

H O RIDDERVOLD and D L SEALE

Patients with marked vascular disease of the pelvic vessels often also have changes in the subclavian and axillary arteries rendering this access to the arterial system for angiography difficult and producing a much higher complication rate than when the translumbar route is employed This paper is intended to re emphasize the usefulness of translumbar catheterization for the examination of the abdominal aorta and its pelvic branches as well as the arteries of the leg when marked intrapelvic arterial changes contraindicate the femoral route

Translumbar aortography was first described in 1929 by DOS SANTOS & PEREIRA CALDERAS the translumbar technique was however not widely employed before the late 40 s and early 50 s

MCAFEE 1957) following a nationwide survey stated that the incidence of serious complications in 13 207 abdominal aortographic examinations was 0 74 per cent The mortality rate for this group was 0 28 per cent the material consisting of 12 832 translumbar and 375 transfemoral catheterizations 234 of the latter were percutaneous transfemoral examinations and in the other 141 the artery was exposed surgically Renal and neurologic complications were preponderant in MCAFEE s survey These two groups included more than half of the serious complications and a little less than half of the deaths Five of the deaths and eight

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serious complications were due to hemorrhage, serious sequelae with deaths were also secondary to cardiovascular and gastrointestinal complications. McAFEE also reported three times as many complications where more than 40 ml of contrast medium had been used, the increase being mainly due to effects upon the kidneys. Injection of contrast medium in one of the renal arteries increased the hazards still further.

Subintimal injection is another serious sequela and deaths have been recorded. The dissection in the cases of serious injury or death had extended into and occluded a branch of the abdominal aorta, usually the renal artery with a resulting necrosis of the kidney. KINCAID encountered major subintimal dissection four times in nearly 2,000 patients although in numerous instances but minor dissection occurred.

Complications of translumbar puncture have been published. Pneumothorax, hydrothorax, pleural effusion and hemothorax have all been reported as well as accidental puncture of the heart and accidental perforation of the subarachnoidal space and viscera of the upper part of the abdomen. Only rarely have these complications resulted in death or permanent disability.

SELDINGER (1953) devised the transfemoral percutaneous catheterization technique that has largely replaced translumbar aortography. This approach is more flexible and allows repositioning of the catheter as well as selective catheterization of the abdominal arteries.

Most complications of percutaneous catheterizations occur at the site of the puncture of the artery. LANG (1963) surveyed 11,402 retrograde percutaneous aortographies reported by 142 radiologists, urologists and vascular surgeons; the review contained 7 deaths and 81 serious complications.

A comparison of the McAFEE and LANG surveys reveals a marked reduction in the mortality in the latter (0.06 per cent compared with 0.28 per cent) with no significant change in the incidence of serious complications (0.7 per cent compared with 0.74 per cent) although a marked difference in type between them. Thus LANG's survey contained 47 serious complications due to arterial thrombosis (58 per cent of the serious sequelae) but only two patients with renal and none with neurologic after-effects, probably due to improved contrast media developed and used in the interim period.

Transfemoral percutaneous catheterization remains the procedure of choice for abdominal aortography in the younger age groups. In older patients, however, with obstructive arteriosclerosis of the pelvic arteries, this approach may be hazardous or even impossible, as in patients with the Leriche syndrome. The best results are then obtained by translumbar aortography performed with a *teflon* catheter which eliminates most of the other complications encountered with the needle technique.

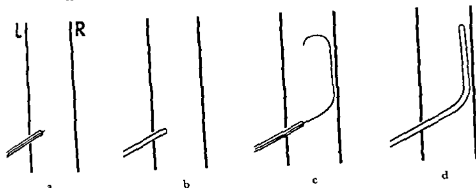


Fig 1 Progressive steps in translumbar catheterization a) Aorta punctured with assembled needle b) Obturator removed If free pulsatile blood flow is observed the steel needle is removed leaving only the flexible teflon sleeve with the tip in the aorta c) Curved spring steel guide wire advanced through teflon catheter (sleeve) with tip pointing cephalad and advanced into aorta d) Catheter and guide wire having been advanced as a unit into lower thoracic aorta the wire is removed and the catheter position checked with contrast medium

Translumbar catheterization of the abdominal aorta with the teflon catheter was first described by AMPLATZ in 1963 a similar technique was also devised by TURNER in 1963 HAUT & AMPLATZ (1968) compared the complication rate in 1 000 percutaneous transfemoral catheterization and 242 translumbar catheterization patients The complication rate for transfemoral catheterization was 1 8 per cent primarily due to post catheterization vascular thrombosis The corresponding rate for translumbar aortic puncture was 0 8 per cent It may be assumed that the complication rate for patients with obstructive iliac disease would have been even higher with a transfemoral approach

STOCKS et coll (1969) reported their experiences with 500 translumbar aortographies They also used the teflon sleeve technique but have recently developed a modification that allows examination of the entire aorta and its branches They had no sequelae in their 500 patients and utilizing a modified technique with a 60 cm catheter also had 15 patients without complications

Technique The procedure is performed under local anaesthesia following premedication with 100 mg Nembutal 25 mg Phenergan and 0 4 mg Atropine An 8 inch teflon catheter is introduced by direct puncture of the aorta with an 18 gauge needle (Becton and Dickinson) above the level of the renal arteries A skin incision is made 2 cm below the left twelfth rib and 8 cm lateral to the spinous process 3 to 4 ml xylocaine 1 % are infiltrated along the projected path of the catheter needle to a depth of 4 to 5 cm (with a No 20 spinal needle) The



Fig. 2. Male aged 71 with marked arteriosclerosis and extravasation of blood after an attempt to perform percutaneous transfemoral catheterization (→).

needle is then introduced in the usual way ventrally and about 45 degrees cephalad and medially guided by fluoroscopy. The needle is advanced 1 cm rapidly when pulsations are encountered; intra-aortic positioning is evidenced by a free pulsatile flow following removal of the obturator. The needle is then withdrawn leaving the teflon catheter in situ. The catheter is advanced after the introduction of the flexible curved guide wire with the tip pointed upwards. The guide wire is pushed about 10 cm into the aorta and the stiff teflon catheter can now be slid over the guide without damage to the aortic wall (Fig. 1). The correct intra-aortic position is ascertained by a small test injection of contrast medium under fluoroscopic control. Seventy ml Renografin 60 % are injected and serial films, usually biplane, obtained. The medium is injected in approximately 4 to 5 seconds. The *filling is improved* by the injection being performed *during* the Valsalva manoeuvre.

Results

Ninety two translumbar catheterizations with a teflon sleeve have been performed in this department since 1966, 81 patients having been examined, one patient four times, 8 patients twice and 72 patients once. Four patients had



F g 3 Translumb r a rtogram in a male aged 59 with the Leriche syndrome and complete aort c cl struction

Fig 4 Female aged 46 ul occlusion of th distal part of the aorta followed by thrombectomy in 1965 a) Recurrent y ptoms with complete oc lusion of the rig t common iliac artery in 1967 f llowed by bilateral venous l ypass graft b) Further recurrent symptoms in 1969 associat d with complete oc lusion on t e left side

transient pain following the examination but required no treatment No other complications were encountered

Fig 3 demontrates a case of the Leriche syndrome and Fig 2 illustrates marked arterioscleros is with extravasation in the region of the right external iliac artery following an attempt at percutaneous transfemoral catheterization A patient examined twice first in 1967 with complete occlusion of the right common iliac artery was subjected to venous bypass graft on both sides (Fig 4) The patient had recurrent symptoms in 1969 with complete occlusion of the left common iliac artery at repeat angiography

The axillary approach is the common one in many centres in patients with severe obstructive arteriosclerosis. This may be technically difficult or even im

possible due to severe tortuosity and arteriosclerosis of the subclavian and innominate arteries. Two patients in the present series were reported to have no axillary pulsations and in 3 patients the axillary route was first tried, but had to be abandoned. However, translumbar catheterization was performed successfully in all 5 patients.

SUMMARY

Transfemoral catheterization in marked obstructive arteriosclerosis of the iliac and femoral arteries may be dangerous and at times impossible. Better results may then be obtained by translumbar aortography with a teflon catheter introduced percutaneously. The procedure was performed successfully and without significant sequelae in 81 patients.

ZUSAMMENFASSUNG

Transfemorale Katheterisierung bei ausgeprägter obstruktiver Arteriosklerose der A. iliaca und der A. femoralis kann gefährlich und gelegentlich unmöglich sein. Bessere Ergebnisse mögen hierbei durch translumbale Aortographie mit einem perkutan eingeführten Teflon-Katheter zu erhalten sein. Dieses Verfahren wurde erfolgreich und ohne schwere Zwischenfällen bei 81 Patienten ausgeführt.

RÉSUMÉ

Le cathétérisme par voie fémorale peut être dangereux et parfois impossible dans les cas d'artériosclérose obstructive grave des artères iliaque et fémorale. On peut alors obtenir de meilleurs résultats par aortographie translombaire avec un cathéter en téflon introduit par voie percutanée. Cette technique a été pratiquée avec succès et sans séquelles importantes chez 81 malades.

REFERENCES

AMPLATZ K. Translumbar catheterization of the abdominal aorta. Radiology *81* (1963), 927.

DOS SANTOS L., A. C. e PEREIRA CALDEIRAS J.: Arteriographia da aorta dos abdominalis. (In Portuguese.) Med. contemp. 47 (1929), 93.

HAUT G. and AMPLATZ K.: Complication rates of transfemoral and transaortic catheterization. Surgery 63 (1968), 594.

KINCAID O. W.: Renal angiography. First edition, p. 73. Year Book Medical Publishers, Chicago 1966.

LANG E. K.: A survey of the complications of percutaneous retrograde arteriography. Seldinger's technique. Radiology 81 (1963), 257.

MCAFEE J. G.: A survey of complications of abdominal aortography. Radiology *68* (1957), 825.

SELDINGER S. I.: Catheter replacement of the needle in percutaneous arteriography. A new technique. Acta radiol. 39 (1953), 368.

STOCKS L. O., HALPERN M. and TURNER A. F.: Complete translumbar aortography. The teflon sleeve technique. Amer. J. Roentgenol. 107 (1969), 835.

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DIAGNOSTISCHE BEDEUTUNG DER SCHICHTUNGSPHÄNOMENE IN DER GALLENBLASE BEI DER CHOLEZYSTOGRAPHIE UND DER CHOLEGRAPHIE

von

M. LINDQVIST und G. F. SALTZMAN

Die Voraussetzung für das Auftreten einer Schichtung in der Gallenblase ist, dass diese Bestandteile mit verschiedenem spezifischen Gewicht enthält. Für das Auftreten solcher Schichtungen auf den Röntgenbildern müssen die verschiedenen Bestandteile auch durch verschiedene Strahlenabsorption gekennzeichnet sein. Am besten tritt die Schichtung auf Bildern hervor, die mit horizontaler Strahlenrichtung hergestellt sind, aber sie kann auch die Beurteilung von Bildern mit vertikaler Strahlenrichtung beeinflussen. Dies alles ist schon seit langem bekannt (BERNSTEIN 1937 u. a.).

Schon 1933 zeigte ÅKERLUND und später KOMERELL (1936), ganz klar den grossen Wert von Bildern mit horizontaler Strahlenrichtung am aufrechtstehenden Patienten. Er zeigte, dass kleine Konkremente in der Gallenblase in einigen Fällen nur auf Bildern hervortraten, wo diese Technik angewandt worden war. Ursache dafür war die Anordnung der Konkremente in einer horizontalen Schicht. Solche Bilder sind seither ein routinemässiger Teil der Cholezystographie an allen Röntgeninstituten in den skandinavischen Ländern gewesen. Zu unserem Erstaunen ist diese Untersuchungstechnik nicht allgemein in anderen Ländern akzeptiert worden.

Bei der Redaktion am 17. Mai 1971 eingegangen.

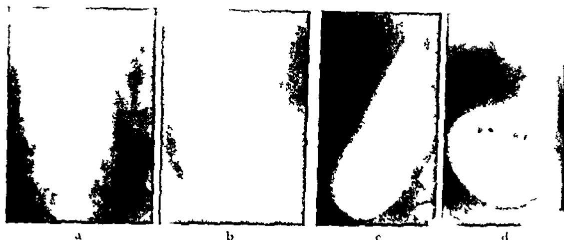


Abb. 1. Cholezystographie. Konkrementschicht in der Gallenblase bei zwei Patienten, die im Stehen mit horizontaler Strahlenrichtung untersucht worden sind. a) und c) vertikale Strahlenrichtung, b) und d) horizontale Strahlenrichtung.

Das Erscheinen der intravenösen Cholegraphie auf der Röntgenbühne gab uns ganz neue Möglichkeiten, die Gallenwege zu untersuchen. Da die Gallenblasen in jenen Fällen, wo Bedingungen für eine Füllung vorhanden waren, dabei mit Kontrast ausgefüllt wurden, ist diese Untersuchungsmethode an mehreren Röntgenabteilungen auch in solchen Fällen benutzt worden, wo die Gallenblase das diagnostische Hauptproblem war. Abgesehen davon, dass die intravenöse Cholegraphie im Vergleich zur Cholezystographie die Anwendung eines bedeutend mehr toxischen Kontrastmittels bedeutet, ist uns die Schichtung, die in der Gallenblase zwischen einerseits kontrastreicher und anderseits kontrastfreier Galle entsteht, als ein ernstes diagnostisches Problem erschienen (Hornykiewytsch 1956, Kaufman 1959, Frik & Cln 1964, Preuss 1970, u. a.).

Unsere Absicht war, an grösseren Materialen nachzuweisen: (1) wie grosse Bedeutung die mit horizontaler Strahlenrichtung gewonnenen Bilder für eine adäquate Gallensteindiagnostik bei der Cholezystographie haben, (2) inwiefern die Kontrastmittelschichtung unsere Gallenblasendiagnostik bei der intravenösen Cholegraphie beeinflussen, (3) wie die Kontrastmittelschichtung bei intravenöser Cholegraphie eliminiert werden kann.

Material und Methoden

Perorale Cholezystographie. 1 000 aufeinander folgende Cholezystographien mit nachgewiesenen Gallensteinen sind nachgeprüft worden. In 52 Fällen wurden kalkhaltige Steine ohne Kontrastfüllung der Gallenblase nachgewiesen. In 62

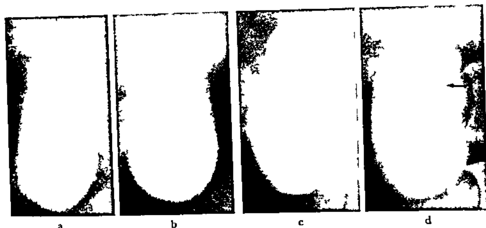


Abb 2 Cholezystographie a) Aufnahme mit vertikaler Strahlenrichtung am liegenden Patienten Konkremente nicht sichtbar b) Aufnahme mit horizontaler Strahlenrichtung am stehenden Patienten Konkrementschicht im mittleren Teil der Gallenblase c) Keine Konkremente sichtbar auf Aufnahme mit vertikaler Strahlenrichtung d) Minimale Konkremente (→) auf Aufnahme mit horizontaler Strahlenrichtung am stehenden Patienten sichtbar

Fällen wo die Gallenblase mit Kontrastmittel gefüllt war sind die Patienten aus verschiedenen Gründen nur in liegender Stellung mit vertikaler Strahlenrichtung untersucht worden Die übrigen 886 Fälle, bei welchen die Gallenblase mit Kontrastmittel angefüllt war sind mit Rücksicht auf die Möglichkeit beurteilt worden die Gallensteine in jenen Bildern zu entdecken, die mit vertikaler bzw horizontaler Strahlenrichtung angefertigt waren

Als Kontrastmittel wurde das Natriumsalz der Jopodsäure (Biloptin Schering) gebraucht Dosis 3 g 12 Stunden vor dem Anfang der Untersuchung

Die Aufnahmen wurden mit vertikaler Strahlenrichtung in Bauch wie Rückenlage und mit horizontaler Strahlenrichtung angefertigt Die Bilder mit hori



Abb 3 Cholezystographie Auf dem Bild mit horizontaler Strahlenrichtung sieht man die Konkremente als eine Schicht (→) auf dem Boden der Gallenblase (b) Mit vertikaler Strahlenrichtung sind die Konkremente nicht sichtbar (a)

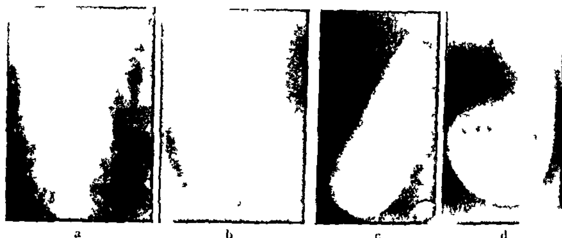


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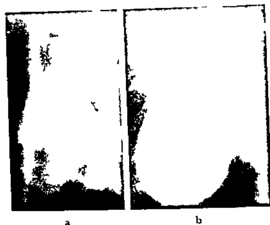


Abb. 7. Cholegraphie. Kontrastmittelschichtung (a): die drei grosse Konkremente völlig verbergen. Auf der Aufnahme mit vertikaler Strahlenrichtung sind sie gut sichtbar (b).

In der grossen Mehrzahl der Fälle ist Joglykamid (Biliwistan, Schering) als Kontrastmittel benutzt worden. Während einer kurzen Periode wurde Jodipamid (Biligrafin forte Schering) benutzt und zwar wegen eines zufälligen Aufhörens der Lieferung von Biliwistan. Biligrafin forte ist nur in etwa 20 Fällen des ganzen Materials injiziert worden und der Kontrastmitteltausch hat auf die Resultate der vorliegenden Arbeit nicht eingewirkt.

Nach langsamer Injektion des Kontrastmittels (Injektionszeit 4—5 min) sind Aufnahmen mit vertikaler Strahlenrichtung am liegenden Patienten mit kurzen Intervallen gemacht worden, bis Kontrast in den Gallenwegen erschien. Gleich nachher bekamen die meisten Patienten 0,1 ml Morphium (1 %) pro 10 kg Körpergewicht und 10—15 min später wurde linear tomographiert. Nach beendeter Tomographie ist der morphiumbedingte Sphinkterspasmus mit 2 ml Cetiprin (Recip) i.m. gelöst worden. Die Untersuchung ist dann, sobald wie möglich 2—4 Stunden nach der Injektion) durch Aufnahmen mit horizontaler Strahlenrichtung vorzugsweise im Stehen ergänzt worden.

In 10 Fällen mit Kontrastmittelschichtung in einer nach intravenöser Cholegraphie mit Kontrast gefüllten Gallenblase wurde ein die Gallenblase kontrahierendes Präparat verabreicht (Emtobil, Astra). Bilder von der Gallenblase mit horizontaler Strahlenrichtung wurden zwanzig Minuten nach Verabreichung von Emtobil exponiert.

In 10 anderen Fällen mit Schichtung in einer nach intravenöser Cholegraphie mit Kontrast gefüllten Gallenblase wurden Bilder der Gallenblase am Tag nach der Kontrastinjektion erneut exponiert. Dem Patienten wurde aufgetragen, in der Zwischenzeit keine die Gallenblase kontrahierende Nahrung zu sich zu nehmen.

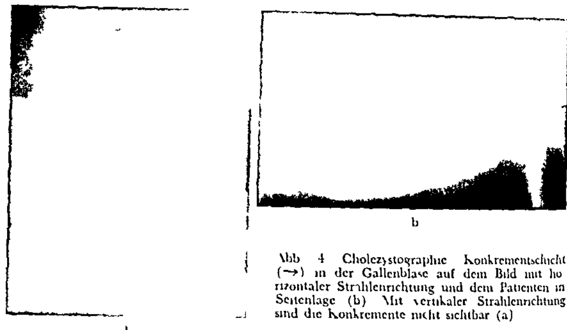


Abb. 4. Cholezystographie. Konkrementschicht (→) in der Gallenblase auf dem Bild mit horizontaler Strahlenrichtung und dem Patienten in Seitenlage (b). Mit vertikaler Strahlenrichtung sind die Konkremente nicht sichtbar (a).

zontaler Strahlenrichtung wurden in der Mehrzahl der Fälle während der Durchleuchtung in aufrechter Stellung des Patienten gemacht. In jenen seltenen Fällen, wenn die Patienten nicht stehen konnten, wurden die Aufnahmen ohne Durchleuchtung in Seitenlage der Patienten und mit horizontaler Strahlenrichtung gemacht.

Cholegraphie. 1 050 aufeinander folgende Cholegraphien sind nachgeprüft worden. In 296 Fällen füllte sich die Gallenblase mit Kontrastmittel. In 199 dieser Fälle wurde die Gallenblase an Aufnahmen untersucht, die sowohl mit vertikaler wie mit horizontaler Strahlenrichtung gemacht wurden. Diese 199 Fälle sollen in dieser Schrift später näher geprüft werden.

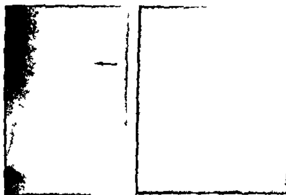


Abb. 5. Cholezystographie. Konkrement (→) in der Gallenblase. Aufnahme mit horizontaler Strahlenrichtung und stehendem Patienten. Da sich das Konkrement ganz nahe an der Grenze zwischen kontrastreicher und kontrastarmer Galle befindet, können weitere Konkremente *nicht* ausgeschlossen werden.

Abb. 6. Cholegraphie. Kontrastarme Schicht am Boden der Gallenblase. Diese Schicht ist einer Konkrementschicht täuschend ähnlich. Bei der Cholezystektomie sofort nach dieser Untersuchung fanden sich aber keine Konkremente.



Abb 9 Aufnahmen mit horizontaler Strahlenrichtung bei Cholezystographie (a) und Cholegraphie (b) Ausser einer kontrastarmen Bodenschicht sind bei der Cholegraphie zwei schmale Schichten (→) welche Konkrementschichten mit sehr kleinen Konkrementen ähnlich sind

Diese drei Untergruppen erfordern weitere Erläuterungen

(1) In dieser Gruppe hatte man bei Untersuchung mit vertikaler Strahlenrichtung die Gallenblase mit grosser Wahrscheinlichkeit in der Mehrzahl der Fälle freiprojizieren können Da die Diagnose schon als sichergestellt betrachtet wurde hat der Untersucher indessen auf diese Ergänzung verzichtet.

(2) Diese Gruppe ist heterogen Sie enthält die Fälle wo wenigstens der eine der beiden Verfasser nicht bereit war an Hand von Aufnahmen mit vertikaler Strahlenrichtung eine sichere Steindiagnose zu stellen In 31 Fällen dieser Gruppe waren die Verfasser einig darüber dass eine sichere Steindiagnose nicht hat gestellt werden können In den übrigen 19 Fällen ist der eine von uns bereit gewesen eine Steindiagnose zu stellen während der andere unschlüssig war oder (in einem Fall) sogar jeden Verdacht auf Gallensteine ausschliessen wollte

(3) Diese Gruppe enthält zum grössten Teil Fälle mit kleinen Konkrementen die in Aufnahmen mit horizontaler Strahlenrichtung sich in einer Schicht gesammelt haben (Abb 2 3) In 19 dieser Fälle hatten die grössten Steine einen Diameter von höchstens 4 mm Nur in einem Fall fanden wir einen grösseren Solitärstein im Gallenblasenfundus Bei den Aufnahmen mit vertikaler Strahlenrichtung war die Gallenblase orthoprojiziert, und der Stein gegen den gut gefüllten Teil der Gallenblase deswegen nicht sichtbar In der Mehrzahl der Fälle wurden die Aufnahmen mit horizontaler Strahlenrichtung bei stehenden Patienten aber in vereinzelten Fällen auch bei Patienten in Seitenlage gemacht (Abb 4

Unser Material enthält eine kleine Gruppe von 12 Fällen (1,4 %) wo man Konkremente auf Aufnahmen mit horizontaler Strahlenrichtung nicht sehen konnte wohl aber auf jenen mit vertikaler Strahlenrichtung In 8 dieser Fälle war bei Aufnahmen mit horizontaler Strahlenrichtung die Gallenblase vom



Abb. 8. Aufnahmen mit horizontaler Strahlenrichtung. Cholezystographie (a) und Cholegraphie (b). Bei der Cholegraphie eine diagnostisch sehr lästige Schichtung. c) und d) Aufnahmen von einem anderen Patienten mit horizontaler Strahlenrichtung. Cholezystographie (c) und Cholegraphie (d). Die Schichtung bei der Cholegraphie ist einem grossen Solitärkonkrement ähnlich.

Ergebnisse

Cholezystographie. In den 886 Fällen, wo die kontrastgefüllte Gallenblase sowohl in liegender Stellung mit vertikaler Strahlenrichtung wie in stehender (evtl. liegender) Stellung mit horizontaler Strahlenrichtung untersucht wurde, hat man Gallensteine an Bildern dieser beiden Kategorien in 700 Fällen (79 %) mit Sicherheit nachweisen können. In einer grossen Zahl dieser Fälle hatten sich die Steine in Aufnahmen mit horizontaler Strahlenrichtung in einer Schicht auf dem Boden der Gallenblase oder auf einem anderen Niveau (Abb. 1) gesammelt.

In 174 Fällen hat man auf Aufnahmen mit horizontaler Strahlenrichtung Konkremente mit Sicherheit beobachten können, während die Aufnahmen mit vertikaler Strahlenrichtung eine sichere Gallensteindiagnose nicht erlauben. Diese letzte Gruppe kann in drei Untergruppen geteilt werden: (1) Fälle wo die Gallenblase auf Aufnahmen mit vertikaler Strahlenrichtung von verdeckendem Darminhalt nicht freiprojiziert war (96 Fälle = 10,8 %). (2) Fälle wo die Steindiagnose auf Aufnahmen mit vertikaler Strahlenrichtung unsicher war, obgleich die Gallenblase vom Darminhalt freiprojiziert war (50 Fälle = 5,6 %). (3) Aufnahmen mit vertikaler Strahlenrichtung und vom Darminhalt freiprojizierter Gallenblase: Kein Verdacht auf Steine (28 Fälle = 3,2 %).

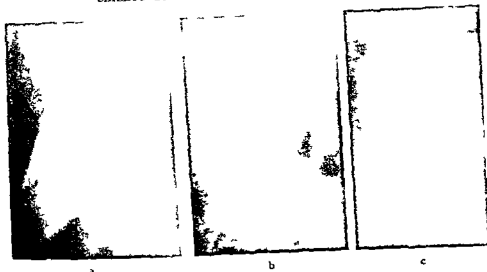


Abb. 11. Cholegraphie. a) Kontrastreiche Galle schichtet sich den Gallenblasenwänden entlang, während die kontrastarme Galle sich in den zentralen Teilen der Gallenblase sammelt (Tomographie). b) Ein anderer Patient. Kontrastreichere Galle schichtet sich auf der Aufnahme mit vertikaler Strahlenrichtung entlang den Wänden der Gallenblase. Ein grosses Solitärkonkrement kann vorliegen. c) Die Aufnahme mit horizontaler Strahlenrichtung zeigt, obgleich eine gewisse Schichtung vorliegt, dass ein solches Konkrement nicht vorhanden ist.

1. In dieser Gruppe konnte keinerlei Schichtung nachgewiesen werden. In einer kleinen Anzahl der Fälle beobachteten wir ein oder einige grosse Konkremente, was aber auf die Beurteilung einer evtl. Kontrastmittelschichtung nicht eingewirkt hat.

2. In sämtlichen Fällen sah man multiple Konkremente. In allen Fällen waren diese auf Aufnahmen mit vertikaler Strahlenrichtung sichtbar. Oft traten diese Konkremente auf Aufnahmen mit vertikaler Strahlenrichtung sogar besser hervor. In allen diesen Fällen bildeten die Konkremente eine Schicht auf dem Boden der Gallenblase. Nie wurde unter diesen Fällen ein Konkrement mit einem Durchmesser kleiner als 4 mm nachgewiesen. Wegen des Vorkommens von multiplen Gallensteinen konnten die Gallenblasen hinsichtlich der Kontrastmittelschichtung nicht beurteilt werden, eine solche konnte allerdings auch nicht ausgeschlossen werden. Die Tatsache, dass die Steine auf Aufnahmen mit horizontaler Strahlenrichtung oft auffallend undeutlich abgegrenzt waren, konnte aber andeuten, dass sich eine Kontrastmittelschichtung doch in dieser Gruppe findet. In den Fällen, wo eine sichere Steindiagnose schon auf Aufnahmen mit vertikaler Strahlenrichtung möglich war, hat die routinemässige Tomographie oft zur Sicherung der Diagnose beigetragen.

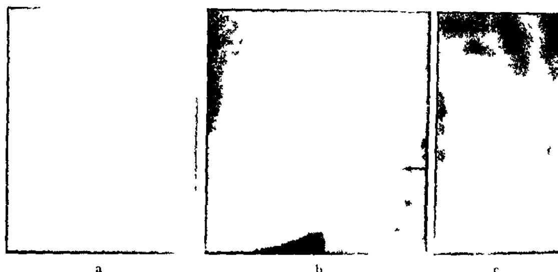


Abb. 10. Aufnahmen mit horizontaler Strahlenrichtung. Cholezystographie sowohl vor (a) wie nach (c) der Cholegraphie (b). Ausser einer kontrastarmen Bodenschicht tritt eine dünne Schicht (→) hervor, die einer Konkrementschicht ähnlich ist.

Darminhalt nicht freiprojiziert worden; in 4 Fällen war die Kontrastkonzentration in der Gallenblase pathologisch niedrig. In keinem dieser Fälle hat man sich besonders bemüht, die Steine durch Aufnahmen mit horizontaler Strahlenrichtung sichtbar zu machen, wahrscheinlich weil die Steindiagnose schon gesichert war.

Schon 1932 zeigte Leiasz, dass eine Schichtung zwischen kontrastführender und kontrastfreier Galle bei der Cholezystographie vorkommen kann. Diese Beobachtung ist später von zahlreichen Forschern bestätigt worden. Dabei legt sich die kontrastführende Galle immer unter die kontrastfreie Galle. Wir haben eine solche Schichtung in einer grossen Zahl von Fällen gesehen, aber *nicht* gefunden, dass diese Schichtung in der Regel diagnostische Schwierigkeiten macht. Wir kennen keinen einzigen Fall, wo man Konkremente einer solchen Schichtung wegen nicht hätte beobachten können. Abb. 5 scheint jedoch dafür zu sprechen, dass eine solche Fehldiagnose nicht ausgeschlossen ist.

Cholegraphie. Die 199 Fälle, bei welchen die Kontrastfüllung der Gallenblase gelungen ist und die Gallenblase durch Aufnahmen mit sowohl vertikaler wie horizontaler Strahlenrichtung untersucht worden ist, verteilen sich folgenderweise hinsichtlich der Schichtung zwischen kontrastführender und kontrastfreier Galle: (1) keine Schichtung 75 Fälle (37,7 %), (2) unsichere Schichtung 29 Fälle (14,6 %), (3) sichere Schichtung 95 Fälle (47,7 %).

Diese Gruppen motivieren gewisse Erläuterungen.

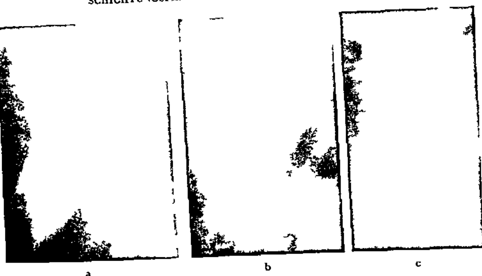
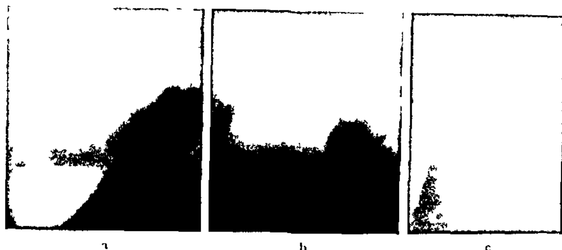


Abb 11 Cholegraphie a) Kontrastreiche Galle schichtet sich den Gallenblasenwanden entlang während die kontrastarme Galle sich in den zentralen Teilen der Gallenblase sammelt (Tomographie) b) Ein anderer Patient Kontrastreichere Galle schichtet sich auf der Aufnahme mit vertikaler Strahlenrichtung entlang den Wanden der Gallenblase Ein grosses Solitärkonkrement kann vorliegen c) Die Aufnahme mit horizontaler Strahlenrichtung zeigt obgleich eine gewisse Schichtung vorliegt dass ein solches Konkrement nicht vorhanden ist.

(1) In dieser Gruppe konnte keinerlei Schichtung nachgewiesen werden In einer kleinen Anzahl der Falle beobachteten wir ein oder einige grosse Konkremente was aber auf die Beurteilung einer evtl Kontrastmittelschichtung nicht eingewirkt hat

(2) In samtlichen Fallen sah man multiple Konkremente In allen Fallen waren diese auf Aufnahmen mit vertikaler Strahlenrichtung sichtbar Oft traten diese Konkremente auf Aufnahmen mit vertikaler Strahlenrichtung sogar besser hervor In allen diesen Fallen bildeten die Konkremente eine Schicht auf dem Boden der Gallenblase Nie wurde unter diesen Fallen ein Konkrement mit einem Durchmesser kleiner als 4 mm nachgewiesen Wegen des Vorkommens von multiplen Gallensteinen konnten die Gallenblasen hinsichtlich der Kontrastmittelschichtung nicht beurteilt werden eine solche konnte allerdings auch sicher nicht ausgeschlossen werden Die Tatsache dass die Steine auf Aufnahmen mit horizontaler Strahlenrichtung oft auffallend undeutlich abgegrenzt waren konnte aber andeuten dass sich eine Kontrastmittelschichtung doch in dieser Gruppe findet In den Fallen wo eine sichere Steindiagnose schon auf Aufnahmen mit vertikaler Strahlenrichtung möglich war hat die routinemassige Tomographie oft zur Sicherung der Diagnose beigetragen



a b c

Abb. 12. Cholegraphie. Schichtung eliminiert nach Verabreichung eines die Gallenblase kontrahierenden Präparates. a) Vor Eintobil, horizontale Strahlenrichtung, b) vor Eintobil, vertikale Strahlenrichtung, c) nach Eintobil, horizontale Strahlenrichtung.

(3) In der Mehrzahl der Fälle war die Schichtung so markant, dass die Gallenblasenbilder mit horizontaler Strahlenrichtung hinsichtlich des eventuellen Vorhandenseins von Konkrementen nicht beurteilt werden konnten. In 5 Fällen war die Schichtung so diskret, dass wir mit grosser Wahrscheinlichkeit glaubten, Gallensteine ausschliessen zu können.

Die Schichtung in der Gallenblase zeigte in den verschiedenen Fällen ein sehr wechselndes Aussehen. In einer grossen Zahl von Fällen legte sich eine kontrastarme Schicht auf dem Boden der Gallenblase, unter eine Schicht mit höherer Kontrastkonzentration (Abb. 6, 7).

Dieser Schichtungstypus konnte in gewissen Fällen zu auffallenden Konsequenzen führen. Bisweilen war die Schichtung so unregelmässig, dass sie in bestechender Weise eine Konkrementschicht vortäuschte. In einem Fall wurden wir zur falschen Gallensteindiagnose verleitet (Abb. 6), ehe wir alle diagnostischen Schwierigkeiten eingesehen hatten. Bisweilen war die kontrastarme Schicht so gross, dass sie Konkremente beträchtlicher Grösse verbergen konnte (Abb. 7).

Etwa ebenso gewöhnlich wie eine kontrastarme Bodenschicht ist eine Schicht, die sowohl aufwärts wie abwärts von kontrastreicherer Galle abgegrenzt ist (Abb. 8, 9, 10). In einigen Fällen hat diese kontrastarme Schicht einen grossen Solitärstein vortäuschen können (Abb. 8 c, d). In anderen Fällen sahen wir multiple solche 'Intermediärschichten', die in hohem Grade Schichten mit ganz kleinen Konkrementen ähnlich waren (Abb. 9, 10).



Abb 13 a) b) Cholegraphie Schichtung nicht eliminiert nach Verabreichung eines die Gallenblase kontrahierenden Praparates a) Vor Emtobil b) nach Emtobil c) Cholezystographie

In Ausnahmefallen sahen wir dass kontrastarme Galle uber kontrastreicherer geschichtet war Dieser Schichtungstypus bot kaum irgend welche Moglichkeit zu Verwechslung mit Gallensteinen

Die Schichtung bei der Cholegraphie bedeutet indessen nicht nur Schwierigkeiten bei der Beurteilung von Aufnahmen mit horizontaler Strahlenrichtung Schon bei solchen Bildern sieht man bisweilen eine gewisse Neigung der kontrastarmen Galle sich zentral in der Blase zu lagern, wahrend die kontrastreichere Galle sich nahe an der Wand sammelt (Abb 8) Diese Neigung ist oft sehr auffallend bei Aufnahmen mit vertikaler Strahlenrichtung (Abb 11) Bisweilen kann die kontrastarme Galle in bestechender Art einem grossen Solitarkonkrement ahnlich sein (Abb 11 b c)

Zehn geschichtete Gallenblasen wurden nach Verabreichung von Emtobil untersucht und zwar mit der Absicht die Schichtung zu eliminieren In 6 Fallen wurde die Schichtung eliminiert (Abb 12) wahrend in 4 Fallen die Schichtung unverandert blieb (Abb 13)

In 10 anderen Fallen wurden die geschichteten Gallenblasen am folgenden Tag erneut untersucht In 4 Fallen wurde die Schichtung eliminiert (Abb 14 a b) in 3 Fallen nahm sie ab sodass ein sicheres Urteil im Hinblick auf das eventuelle Vorkommen von Konkrementen fur moglich gehalten wurde (Abb 14 c d 15) In den restlichen 3 Fallen befand sich kein Kontrast mehr in der Gallenblase obwohl man die Patienten dazu angehalten hatte keine die Gallenblase kontrahierende Nahrung zu sich zu nehmen

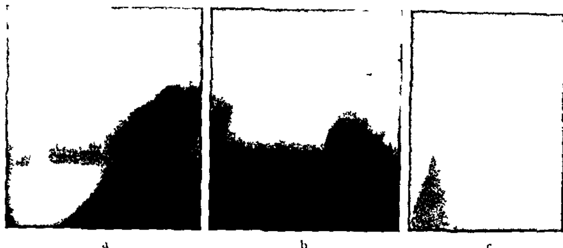


Abb. 12. Cholegraphie. Schichtung eliminiert nach Verabreichung eines die Gallenblase kontrahierenden Präparates. a) Vor Entmobil horizontale Strahlenrichtung. b) vor Entmobil vertikale Strahlenrichtung. c) nach Entmobil horizontale Strahlenrichtung.

(3) In der Mehrzahl der Fälle war die Schichtung so markant, dass die Gallenblasenbilder mit horizontaler Strahlenrichtung hinsichtlich des eventuellen Vorhandenseins von Konkrementen nicht beurteilt werden konnten. In 5 Fällen war die Schichtung so diskret, dass wir mit grosser Wahrscheinlichkeit glaubten, Gallensteine ausschliessen zu können.

Die Schichtung in der Gallenblase zeigte in den verschiedenen Fällen ein sehr wechselndes Aussehen. In einer grossen Zahl von Fällen legte sich eine kontrastarme Schicht auf dem Boden der Gallenblase, unter eine Schicht mit höherer Kontrastkonzentration (Abb. 6, 7).

Dieser Schichtungstypus konnte in gewissen Fällen zu auffallenden Konsequenzen führen. Bisweilen war die Schichtung so unregelmässig, dass sie in bestechender Weise eine Konkrementschicht vortäuschte. In einem Fall wurden wir zur falschen Gallensteindiagnose verleitet (Abb. 6), ehe wir alle diagnostischen Schwierigkeiten eingesehen hatten. Bisweilen war die kontrastarme Schicht so gross, dass sie Konkremente beträchtlicher Grösse verbergen konnte (Abb. 7).

Etwa ebenso gewöhnlich wie eine kontrastarme Bodenschicht ist eine Schicht, die sowohl aufwärts wie abwärts von kontrastreicherer Galle abgegrenzt ist (Abb. 8, 9, 10). In einigen Fällen hat diese kontrastarme Schicht einen grossen Solitärstein vortäuschen können (Abb. 8 c, d). In anderen Fällen sahen wir multiple solche 'Intermediärschichten', die in hohem Grade Schichten mit ganz kleinen Konkrementen ähnlich waren (Abb. 9, 10).

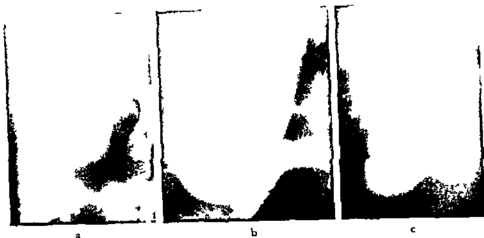


Abb. 13. a), b) Cholegraphie. Schichtung nicht eliminiert nach Verabreichung eines die Gallenblase kontrahierenden Präparates. a) Vor Emtobil, b) nach Emtobil. c) Cholezystographie

In Ausnahmefällen sahen wir, dass kontrastarme Galle über kontrastreicherer geschichtet war. Dieser Schichtungstypus bot kaum irgend welche Möglichkeit zu Verwechslung mit Gallensteinen.

Die Schichtung bei der Cholegraphie bedeutet indessen nicht nur Schwierigkeiten bei der Beurteilung von Aufnahmen mit horizontaler Strahlenrichtung. Schon bei solchen Bildern sieht man bisweilen eine gewisse Neigung der kontrastarmen Galle, sich zentral in der Blase zu lagern, während die kontrastreichere Galle sich nahe an der Wand sammelt (Abb. 8). Diese Neigung ist oft sehr auffallend bei Aufnahmen mit vertikaler Strahlenrichtung (Abb. 11). Bisweilen kann die kontrastarme Galle in bestechender Art einem grossen Solitärkonkrement ähnlich sein (Abb. 11 b, c).

Zehn geschichtete Gallenblasen wurden nach Verabreichung von Emtobil untersucht, und zwar mit der Absicht, die Schichtung zu eliminieren. In 6 Fällen wurde die Schichtung eliminiert (Abb. 12), während in 4 Fällen die Schichtung unverändert blieb (Abb. 13).

In 10 anderen Fällen wurden die geschichteten Gallenblasen am folgenden Tag erneut untersucht. In 4 Fällen wurde die Schichtung eliminiert (Abb. 14 a, b), in 3 Fällen nahm sie ab, sodass ein sicheres Urteil im Hinblick auf das eventuelle Vorkommen von Konkrementen für möglich gehalten wurde (Abb. 14 c, d, 15). In den restlichen 3 Fällen befand sich kein Kontrast mehr in der Gallenblase, obwohl man die Patienten dazu angehalten hatte, keine die Gallenblase kontrahierende Nahrung zu sich zu nehmen.

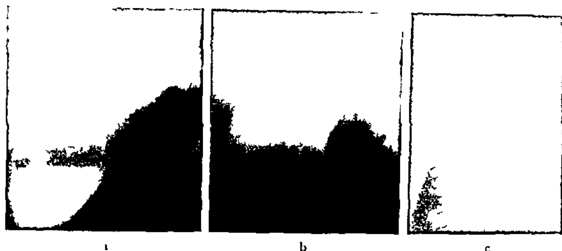


Abb. 12. Cholegraphie Schichtung, eliminiert nach Verabreichung eines die Gallenblase kontrastierenden Präparates. a) Vor Emtobil horizontale Strahlenrichtung. b) vor Emtobil vertikale Strahlenrichtung. c) nach Emtobil horizontale Strahlenrichtung.

(3) In der Mehrzahl der Fälle war die Schichtung so markant, dass die Gallenblasenbilder mit horizontaler Strahlenrichtung hinsichtlich des eventuellen Vorhandenseins von Konkrementen nicht beurteilt werden konnten. In 5 Fällen war die Schichtung so diskret, dass wir mit grosser Wahrscheinlichkeit glaubten, Gallensteine ausschliessen zu können.

Die Schichtung in der Gallenblase zeigte in den verschiedenen Fällen ein sehr wechselndes Aussehen. In einer grossen Zahl von Fällen legte sich eine kontrastarme Schicht auf dem Boden der Gallenblase, unter eine Schicht mit höherer Kontrastkonzentration (Abb. 6, 7).

Dieser Schichtungstypus konnte in gewissen Fällen zu auffallenden Konsequenzen führen. Bisweilen war die Schichtung so unregelmässig, dass sie in bestechender Weise eine Konkrementschicht vortäuschte. In einem Fall wurden wir zur falschen Gallensteindiagnose verleitet (Abb. 6), ehe wir alle diagnostischen Schwierigkeiten eingesehen hatten. Bisweilen war die kontrastarme Schicht so gross, dass sie Konkremente beträchtlicher Grösse verbergen konnte (Abb. 7).

Etwa ebenso gewöhnlich wie eine kontrastarme Bodenschicht ist eine Schicht, die sowohl aufwärts wie abwärts von kontrastreicherer Galle abgegrenzt ist (Abb. 8, 9, 10). In einigen Fällen hat diese kontrastarme Schicht einen grossen Solitärstein vortäuschen können (Abb. 8 c, d). In anderen Fällen sahen wir multiple solche 'Intermediärschichten', die in hohem Grade Schichten mit ganz kleinen Konkrementen ähnlich waren (Abb. 9, 10).

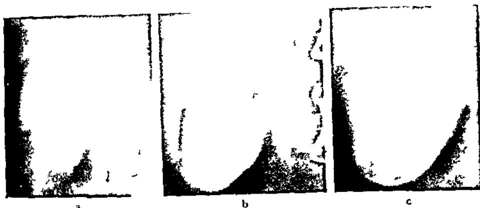


Abb 15 a) b) Cholegraphie Schichtung eliminiert nach einem Tag Wartezeit sodass eine sichere Steindiagnose möglich geworden ist Erster Tag (a) zweiter Tag (b) c) Cholezystographie Zu beachten sind die unterschiedlichen Lagen der Steinschicht bei den einzelnen Untersuchungen

Schichtung phänomene unmöglich Bei Aufnahmen mit horizontaler und auch mit vertikaler Strahlenrichtung können Schichtungsphänomene Gallensteine vortäuschen

Es muss betont werden dass die Schichtung bei der Cholegraphie (und bei der Cholezystographie) oft mit einem die Gallenblase kontrahierenden Agens eliminiert werden kann (TRIGO & ZELNA 1963 NEWMAN et coll 1968) Dadurch wird aber die an und für sich zeitraubende Prozedur weiter verlängert. Unsere Untersuchungen zeigen ausserdem dass die Verabreichung von Präparaten die die Gallenblase kontrahieren nicht in sämtlichen Fällen die Eliminierung der Schichtung bewirkt

BLOCH & PECK (1966) führen an dass die Kontrastmittelfüllung in der Gallenblase homogen wird wenn man lange genug wartet Aus unserem Material ist ersichtlich dass eine Zeitspanne von 2—4 Stunden zwischen Injektion und Exponierung die Schichtung nicht zu eliminieren vermag Eine längere Wartezeit scheint in vielen Fällen die Schichtung eliminieren zu können, wenigstens in dem Au mass dass ein sicheres Urteil im Hinblick auf ein eventuelles Vorkommen von Gallensteinen abgegeben werden kann Die Schichtung kann auch in manchen Fällen mit Präparaten die die Gallenblase kontrahieren, eliminiert werden

Die intravenöse Cholegraphie bei der Untersuchung der Gallenblase ist schon aus kontrastmitteltoxikologischen Gründen kontraindiziert Ein toxischeres Mittel anzuwenden wo mit weniger toxischen Mitteln ebenso gute oder bessere Resultate erreicht werden können ist kaum zu rechtfertigen Die einzige Situation bei der die intravenöse Cholegraphie unserer Meinung nach erlaubt ist sind die

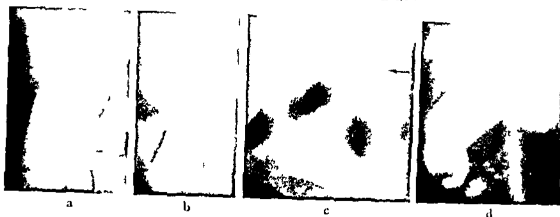


Abb. 11. Cholegraphie. a), b) Schichtung eliminiert nach einem Tag Wartezeit. Keine Konkremente. Erster Tag (a), zweiter Tag (b). c), d) Schichtung (→) eliminiert nach einem Tag Wartezeit, sodass eine sichere Steindiagnose möglich geworden ist. Erster Tag (c), zweiter Tag (d).

Diskussion und Schlussfolgerungen

Die Cholezystographie mit sowohl vertikaler wie horizontaler Strahlenrichtung ist eine praktisch 100 prozentig zuverlässige Untersuchungsmethode, wenn es gilt Steine in der Gallenblase zu entdecken (Wickbom & Rentzhog 1955). Die Tatsache, dass bei der Cholezystographie vielerorts, mit Ausnahme von den skandinavischen Ländern, nur Aufnahmen mit vertikaler Strahlenrichtung gemacht werden, deutet darauf hin, dass man mit dieser einfacheren Untersuchungstechnik zufrieden ist. Die vorliegende Untersuchung zeigt aber, dass in 3—4 % aller Fälle nur in Aufnahmen mit horizontaler Strahlenrichtung Steine sichtbar waren.

Solche Bilder waren notwendig, um die beiden Verfasser dieser Arbeit in sogar 8—9 % aller Fälle zu überzeugen, dass Gallensteine in der kontrastgefüllten Blase in der Tat vorhanden waren. In der einzigen Frequenzuntersuchung dieser Art (Hoffman 1957), die wir in der Literatur gefunden haben, meint der Verfasser eine höhere Frequenz von Fällen gefunden zu haben, wo Bilder mit horizontaler Strahlenrichtung für eine sichere Steindiagnose nötig waren (24 %). Dieses Material ist aber ziemlich klein.

Viele Verfasser haben darauf hingewiesen, dass Schichtungsphänomene in der Gallenblase bei allen zur Verfügung stehenden Kontrastmittel für Cholegraphie auftreten, aber eine systematische Untersuchung der diagnostischen Konsequenzen dieser Schichtung ist unseres Wissens früher nicht veröffentlicht worden. Die verbreitete Anwendung der intravenösen Cholegraphie für die Untersuchung der Gallenblase bedeutet aber, dass man die diagnostische Sicherheit dieser Methode sehr hoch geschätzt hat. Wir können aber diese Auffassung nicht teilen. In fast der Hälfte aller Fälle ist eine zuverlässige Gallensteindiagnostik wegen der

RÉSUMÉ

Les auteurs ont examiné un grand nombre de cas de *cholécystographie par voie orale et* de cholégraphie par voie intraveineuse pour étudier l'intérêt diagnostique des différents phénomènes de sédimentation dans la vésicule biliaire. La sédimentation de petits calculs *dans la vésicule a une si grande* importance diagnostique que l'examen avec un rayonnement horizontal doit être considéré comme une partie obligatoire de la cholécystographie par voie orale. La sédimentation entre *la bile riche en moyen de contraste* et la bile pauvre en moyen de contraste au cours de la cholégraphie intraveineuse est un argument plus important que la toxicité du moyen de contraste contre l'emploi de la cholégraphie *comme méthode principale* pour l'examen de la vésicule biliaire.

SCHRIFTTUM

AKERLUND, A.: Beobachtungen bei Cholezystogrammen in aufrechten Körperstellungen: ein neues röntgenologisches Gallensteinsymptom. Acta radiol. *14 (1933)*, 74.

— Die Verfeinerung der röntgenologischen Gallensteindiagnostik durch Untersuchung der Sedimentierungs- und Schichtungsverhältnisse in der Gallenblase. Acta radiol. 19 (1938), 23.

BECKER, J., BORGSTRÖM, S. and SALTZMAN, G. F.: Acute intravenous cholegraphy. To be published in Acta chir. scand.

BERNSTEIN, A.: Die Gallenschichtung und das Symptom der horizontal schwimmenden Steinschicht. Fortschr. Röntgenstr. 55 (1937), 570.

BLOCH, C. and LECK, H. M.: Radiological notes. Case No. 267. J. Mt. Sinai Hosp. 33 (1966), 519.

CIMMINO, C. V.: Experiences with the upright fluoroscopic spot film examination of the gall bladder. Radiology 67 (1956), 74.

ELIASZ, E.: Neuere Gesichtspunkte bei der röntgenologischen Funktionsprüfung der Gallenblase. Fortschr. Röntgenstr. 46 (1932), 402.

FRIK, W. *und* GEN, M.: *Klinische Erfahrungen mit einem neuen injizierbaren* Gallenkontrastmittel. Arzneimittel Forsch. 14 (1964), 454.

HOFFMAN, C. R.: Phototimed erect compression spot films in cholecystography. Amer. J. Roentgenol. 77 (1957), 55.

HORNYKIEWYTSCH, T.: Intravenöse Cholangiographie. Georg Thieme Verlag, Stuttgart 1956.

KAUFMAN, S. A.: Stratification (layering) of bile in the normal gall bladder. Amer. J. dig. Dis. 4 (1959), 634.

KOMERELL, B.: Schwimmende und schwebende Gallensteine. Klin. Wschr. 15 (1936), 743.

NEWMAN, H., DITCHEK, T. and MASON, R.: Stratification *of bile in the normal* gall bladder during intravenous cholangiography. Amer. J. dig. Dis. 13 (1968), 719.

PREUSS, H. J.: Schichtungsphänomene *der Gallenblase* bei der intravenösen Cholangiozystographie — Ausdruck der resorptiven Schleimhautfunktion? Fortschr. Röntgenstr. 112 (1970), 219.

TRIGG, H. L. and ZELNA, A.: Stratification in intravenous cholangiography. Radiology 80 (1963), 774.

WICKBOM, I. *and* RENTZHOG, U.: The reliability of cholecystography. Acta radiol. 44 (1955), 185.

akuten Bauchfälle, wo akute Cholezystitis als klinische Alternative betrachtet werden kann (BECKER et coll., u. a.). Der Zeitgewinn ist in diesen Fällen ein entscheidender Vorteil. Wir möchten aber hervorheben, dass wir dabei nur feststellen wollen, ob die Gallenblase sich mit Kontrast füllt, und dass es sich nicht um eine detaillierte Gallenblasendiagnostik handelt.

Unsere Erfahrungen erlauben folgende Schlussätze: (1) Für den Nachweis von *Steinen in der Gallenblase* ist die Cholezystographie die Methode der Wahl. (2) Wir teilen die Auffassung von ÅKERLUND (1938) and CIMMINO (1956), dass es bei Cholezystographie ein Kunstfehler wäre, die Aufnahmen mit horizontaler Strahlenrichtung zu unterlassen, falls man auf Aufnahmen mit vertikaler Strahlenrichtung Steine nicht sicher nachweisen kann. (3) Die intravenöse Cholegraphie ist schon aus kontrastmitteltoxikologischen Gründen kontraindiziert, wenn es gilt, die Gallenblase spezifisch darzustellen. Die intravenöse Cholegraphie ist auch auf Grund der Schichtungsphänomene weniger zur Konkrementdiagnostik geeignet als die perorale Cholezystographie. (4) In den Fällen, wo eine Cholegraphie indiziert ist bei Patienten mit noch vorhandener Gallenblase, und diese mit Kontrast gefüllt wird, kann eine im Hinblick auf die Diagnose störende Kontrastmittelschichtung oft, aber nicht immer, eliminiert werden und zwar entweder durch Verabreichung von Präparaten, die die Gallenblase kontrahieren, oder dadurch, dass die Gallenblase am folgenden Tag erneut untersucht wird.

ZUSAMMENFASSUNG

Ein grosses Material von peroralen Cholezystographien und intravenösen Cholegraphien wurde im Hinblick auf die diagnostische Bedeutung verschiedener Schichtungsphänomene in der Gallenblase geprüft. Die Schichtung von kleinen Konkrementen in der Gallenblase ist diagnostisch so wichtig, dass die Untersuchung mit horizontaler Strahlenrichtung als obligatorischer Teil der peroralen Cholezystographie angesehen werden muss. Die Schichtung zwischen kontrastreicher und kontrastarmer Galle in der Gallenblase bei intravenöser Cholegraphie ist über die Kontrastmitteltoxizität hinaus ein starkes Argument gegen die Anwendung der Cholegraphie als Hauptmethode für die Untersuchung der Gallenblase.

SUMMARY

The diagnostic significance of various phenomena of layering in the gallbladder were reviewed in a large material of cases of cholecystography and intravenous cholegraphy. The layering produced by small calculi in the gallbladder is so important that films exposed with a horizontal roentgen beam must be regarded as an essential part of cholecystography. Apart from the matter of toxicity, layering between contrast rich and contrast poor bile in intravenous cholegraphy is a strong argument against its employment as the chief method of gallbladder examination.

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TOMOGRAPHY OF THE LUMBAR INTERVERTEBRAL JOINTS

by

SVEN REICHMANN

PUTTI (1927) rai ed the question whether pathologic states within the lumbar intervertebral joints should be regarded as a common cause of low back pain GUNTZ (1933/34) and LEUBNER (1936) demonstrated morphologically that arthrosis frequently occurs in these joints their observations later being confirmed by INGELMARK (1959) and LEWIN (1964) GUNTZ (1933/34) and LAWRENCE et coll (1964) described true arthritis of the joints A reliable roentgen method of diagnosing pathologic changes in these joints is thus much to be desired

The lumbar intervertebral joints were investigated radiographically by several investigators during the 1920s and the 1930s (PUTTI 1927 DITTMAR 1929 a b, HUBENY 1931 LYON 1933 GHORMLEY & KIRKLIN 1934 LANGE 1936, MORTON 1937 OPPENHEIMER 1938) PUTTI described the radiographic changes occurring in arthritis although from his description he may equally well have meant arthrosis The main interest of the other investigators as regards pathologic states was devoted to arthro is

The main interest after the 1930s was directed towards the intervertebral discs. Unfortunately the pinal joints were then largely di regarded o that

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HAEMANGIOSARCOMA OF KAPOSI By P L S Palmer 52 pages with 23 illustrations Acta radiol (1972) Suppl No 316 Price Sw Kr 35

The haemangiosarcoma first described by Kaposi has been of great interest to pathologists to clinicians and recently to radiologists This monograph discusses a series of 242 patients with histologically proven disease The emphasis is on the radiologic findings but the current literature has been reviewed and the implications of the natural history of the disease are discussed

The histologic changes in Kaposi s sarcoma are universally identical It does not matter from which part of the world the patient comes nor is there any significant racial distribution (contrary to what has been commonly thought) The disease is much more common in men than in women, but about 4 % of the patients will be children under 16 years of age

The clinical history and findings are described in detail and are the same the world over There are three clinical categories The first is a relatively benign disease with which the patient lives for many years the second is much more malignant and death may follow rapidly in a few months or a year or two In the third important group are those in whom second primary malignancy develops concurrently with the haemangiosarcoma Some confusion has arisen because patients in Europe and America are commonly in the first and third categories and have been considered different from those who suffer from the disease in Tropical Africa But a careful review of individual cases and numerous case histories shows that the eventual outcome and the natural history of the disease is really the same in all races it is only the time span which is different The more benign type of disease starts in the sixth or seventh decade the malignant variety starts either in childhood or in the fourth decade The benign type may occasionally become malignant particularly under the influence of steroid therapy

The radiologic changes have been neglected but are important and frequently very significant The soft tissue nodules which are part of the disease entity can be demonstrated by angiography before they can be discovered clinically Local changes appear within bones but these are less specific The nodules can also be filled on lymphangiography and all the radiologic findings confirm the clinical and histologic changes

Haemangiosarcoma of Kaposi is not a skin disease Abdominal involvement probably occurs towards the end in almost every patient The radiologic findings in the gut are not often demonstrated but the radiologist should be aware that they can occur so that in a patient with known Kaposi sarcoma he may arrive at the correct diagnosis The lungs the heart and the kidney may all be involved and the disease is often widespread before death It is the overall picture of Kaposi s sarcoma both radiologically and clinically which is diagnostically important

Angiography has a most significant part to play in choosing the correct treatment and control The disease can be treated either by radiation therapy or by chemotherapy the choice is largely dependent on the extent as demonstrated by angiography This is a disease which may not alter the patient s life span whereas in other cases it progresses rapidly There is a statistically significant association with other malignancies especially lymphomas and there is no doubt that immunology plays a part in the behaviour of the disease Patients on immunosuppressive therapy may develop Kaposi sarcoma when least expected or if already suffering from the disease it may progress rapidly under such treatment

The geographical distribution the behaviour of the disease in different countries *together* suggest that this is a malignancy closely related to the immune pattern of the particular patient

Iutoretica

An intervertebral joint is built up of two articular processes of adjacent vertebrae The inferior articular process arises from the vertebra above and has the joint surface at its anterolateral a pect (cf Fig 4 a) The superior articular process from the vertebra below, has a concave joint surface at its posteromedial aspect All joints in Figs 1 2 and 3 are depicted as if they belonged to the right side of the body o as to simplify the comparison The superior articular process comes up from the lower left part of the illustrations to meet the inferior process from above The free end of the articular process is called the apex although the form of this region in the anatomic specimen does not correspond to this term at the other end is the base The interface between the joint cartilage and the underlying bone will be called the osseous joint surface In the tomograms these osseous joint surfaces limit the joint pace

The tomographic terms are spurious contours and tomofluoro copy

Spurious contours have been investigated by REICHMANN (1972 b) Such contours were defined as derived from object parts situated o far outside the tomographic plane that they should normally have been blurred although no blurring is visible due to a defect in the image generation of the tomograph The best known example is the occurrence of o called parasite shadows in linear tomography derived from object parts situated outside the tomographic plane such contours being encountered in all types of tomography available at present. There is always a risk that the spurious contours will give misleading information since they obtain their form not only from the shape of the object but also from that of the tomographic movement path The reliability of a tomographic method depends to a large extent on how much the spurious contours interfere with the interpretation of the true contours, i e those contours that provide true information about the object

Tomofluoroscopy is a method of determining by fluoroscopy the most appropriate level for the tomographic plane before tomography on film (REICHMANN 1972 d) The tomograph hould be coupled with a TV unit that can participate in the movement If the movement of the tomographic system be carried out during the fluoroscopy as is the condition necessary for tomofluoroscopy the contours in the TV image will move on the screen in a way determined by the level of the tomographic plane Characteristic movements thus appear in those contours that will be depicted sharply in the final tomogram The level of the tomographic plane is changed during the fluoroscopy until it passes through the structures that are to be depicted in the film tomogram The examination time is consequently cut down and possibly the roentgen do e as well

attempts at devising reliable roentgen diagnostic procedures gradually ceased. Clinical investigations of the lumbar intervertebral joints have occasionally been published during the last three decades (BADGLEY 1941, PHEASANT & SWENSON 1942, FRIEDMAN et coll. 1946, HADLEY 1961, HORVATH & MASSANYI 1962, BUSE 1963, CALLAN et coll. 1966, PALVOLGYI 1968, PFEIL 1968) although the publications have contributed little to the improvement of radiographic diagnostics. An excellent review of the current position in roentgen diagnosis of the lumbar joints has been published by REINHARDT (1963).

The question of how a roentgen examination should be carried out to give optimal results has been barely considered. Conventional radiography used to be the rule, the only problem dealt with was the choice of projection, this being investigated only in uncontrolled series. HOLWITZ & SMITH (1940) in discussing the anatomy of the lumbar intervertebral joint surfaces, suggested that a satisfactory projection could possibly not be found because of the anatomic variations between different joints in one subject as well as between the same *joint in different subjects*. LEDMANN (1967) arrived at the same conclusion from clinical experience, namely that ordinary radiography was unlikely to be reliable. This has lately been confirmed in a controlled investigation by REICHMANN (1972 c).

All previous descriptions of the normal roentgen appearances of the lumbar joints have thus been based on an unreliable roentgen method and this is reason enough for their validity being questioned. However the descriptions were in themselves rather meagre, probably owing to the fact that most authors were unaware of the considerable anatomic variations. Clinical radiography of the lumbar joints in pathologic conditions cannot be investigated before a reliable roentgen method has been developed and the variations in the normal roentgenogram obtained by the method have been determined.

The roentgen method used in the present investigation was tomography with a hypocycloid movement at an angle of 18°. The considerations leading to the choice of this method will be described in the discussion. *The following* questions are dealt with: (a) The tomographic image of normal lumbar intervertebral joints including normal variations. (b) The reliability and the usefulness of the *tomographic method. The reason why* the type of tomography used should be superior to conventional radiography. (c) The means by which the examination is carried out in clinical practice.

Although tomograms of lumbar intervertebral joints have been published earlier (BROCHER 1966, SCHMORL & JUNGHANNS 1968) no systematic investigation appears to have been performed.

Two groups of terms will be considered, namely anatomic terms and those belonging to the tomographic process.

visible in the multisection tomograms were chosen for single tomography The total number of tomographic series from the group of living subjects was 26

The technical data in the investigation of the living subjects were as follows Focus size 0 6 mm $\times$ 0 6 mm Tube potential usually 72 to 85 kV—62 kV in one 0 projection and 100 kV in three 60° projections. The multisection and single tomographic voltages were the same, a grid was used only in single tomography The multisection screen series was of Siemens type II the properties of which were better compared with other multisection screen types (WIEDEMANN 1958) the screens and the cassette are marketed by Siemens as being standard for the Multiplanigraph The multisection cassette was mounted on a special adapter to fit into the cassette holder of the Polytome The screens in single tomography were Siemens Saphir with Kodak RP film developed in a roll machine

Since investigation of living subjects proved that this form of tomography of the lumbar joints may be carried out in such a way as to produce acceptable tomograms the postmortem material presented below was investigated A direct comparison between the tomogram and the anatomic specimen was possible and increased the accuracy considerably

Postmortem material This was intended to contain spines from those aged 20 to 45 who died after only a few days of illness The upper age limit was chosen in accordance with the report of LEWIN (1964) that macroscopic arthrosis is encountered in a rapidly rising frequency after this age Twelve spines were excised but from this material one spine was later excluded owing to widespread pathologic changes of a degenerative nature The actual age limits of the remaining 11 spines were 21 to 42 years 10 patients were males Since both sides were investigated the total number of joints amounted to 110 However 9 joints were damaged by the excision of the spines and 2 had to be excluded for other reasons The final number of joints was thus 99 (Table 1)

People between 20 and 45 years of age dying suddenly nearly always do so as a result of an accident or suicide When the collection of spines started, such an overrepresentation of those addicted to alcohol, sedatives or narcotic drugs occurred in both these groups that this kind of chronic condition could not be completely avoided Care was taken to exclude those in whom the autopsy revealed signs of secondary changes in the organs No corpse had signs of recent injections The diagnoses were as follows suicide in 4 cases accident without trauma to the lumbar spine in 5 cases femoral vein thrombosis with pulmonary embolism in 1 case (no other disease was evident the subject had not been lying in bed) The last case a pregnant woman seemed to have died from over indulgence of alcohol Apart from this some kind of addiction was present in

Table 1

The number of joints examined in the two parts of the material and their segmental distribution

Segment	Living subjects		Postmortem material	
	Exclusion	Final number	Exclusion	Final number
L1—L2	1	10	5	17
L2—L3	0	11	3	19
L3—L4	0	11	2	20
L4—L5	0	11	0	22
L5—S1	0	11	1	21
Total	1	54	11	99

Material and Methods

The investigation was performed in living subjects as well as in lumbar spines excised at autopsy.

Living subjects. The living subjects were 11 healthy medical students aged between 20 and 24 years, only males were investigated, it being considered desirable to shield the gonads from roentgen rays. None displayed signs of spinal disease. Only one side was examined in each subject, both sides being equally represented in the whole group of living subjects. All lumbar intervertebral joints between L1 and S1 were examined in at least two projections. The total number of segments was 55, one joint was however absent due to aplasia, bringing the final number of joints to 54 (Table 1). Radiography disclosed no pathologic conditions, no spondylolysis was evident.

The living subjects were examined before the postmortem cases which are described below. Following radiography of the lumbar spine in a.p. and lateral projections, tomography by means of a Polytome was then performed with a hypocycloid movement and a 48° angle. In the first 8 cases the projections were obtained with the subject supine (the '0° projection') and turned 40° on the side to be examined (the '40° projection'). The procedures for measuring the angle of rotation and immobilizing the subject are described elsewhere (REICHMANN 1972 a). The 40° projection had however in four cases to be supplemented with a 60° projection for the depiction of joints with a relatively frontal orientation of their surfaces, so that the projections in the rest of the material were performed at a rotation of 20° and 50° from the supine position instead of 0° and 40°. When the subjects had been placed in the desired position, a seven film multisection tomogram was obtained, the distance between adjacent films corresponding to a distance of 4 mm between the tomographic planes. After development those tomographic planes in which a joint space was

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3 other cases The roentgen appearances of the intervertebral joints of these four cases did not however differ appreciably from that of the other cases, so they were retained within the material in spite of the addiction Three of the 11 cases had bilateral spondylolysis, this being present in L4 in one of them

The excised lumbar spines were investigated in the 20° and 50° projections, this was from experience gained in the living subjects The spines were fixed in a specially designed specimen holder in which they could be rotated along the longitudinal axis, the angle of rotation being determinable by means of a protractor Fluoroscopy was used for the calibration of the protractor, it was placed at 90° when the spine was in a lateral projection as judged from the posterior surfaces of the vertebral bodies Hypocycloid tomography at a 48° angle was carried out with a Polytome, the distance between adjacent tomographic planes being 3 mm The focus size, the film and the development were the same as already described, potential 43 kV Siemens Ruby screens without grid were used Only single tomography was performed

One further examination was made in 5 of the excised lumbar spines

Since tomofluoroscopy can be performed only by means of television fluoroscopy, an investigation was carried out to determine whether the positioning of the patient could also be determined fluoroscopically, thus minimizing the total number of projections and the total roentgen dose to the patient The 6" image intensifier obtainable as standard equipment for the Polytome was used in combination with a Plumbicon TV camera The small size of the image intensifier made it necessary to make two positionings for each side of the spine in one the L1—L2 and L2—L3 joints were included, the other centering being made for the three lower segments The excised spines were rotated in the specimen holder until the perpendicular roentgen beam seemed to depict the joint spaces optimally Tomofluoroscopy was then performed to centre the level of the tomographic plane Three tomograms were usually obtained, the distance between adjacent planes being 5 mm The procedure was performed twenty one times, one joint with unusually plane joint surfaces demanding special centering, after positioning the angle of rotation of the spine was noted in all cases but one in which it was accidentally forgotten The tomograms from these series were compared with those obtained in standard projections from the same spines as those described Any variations in the normal roentgen appearances when standard positioning was replaced by individualized positioning by means of fluoroscopy were thus determined

The tomograms of the excised spines having been taken the latter were macerated The joints as well as other parts of the vertebrae were scrutinized for pathologic changes which led to part of the rejection mentioned above As regards the joints, the criteria of arthrosis formulated for intervertebral joints by INGEL

MARK (1959) and SAGER (1969) were used There were *no joints with signs* suggesting changes other than those due to arthrosis, the condition most common in these joints (LEWIN 1964)

The total number of joints investigated when the two parts of the material were considered together was 153 The number of individuals was 22 the *material is summarized* in Table 1

The tomograms of the living subjects were examined before the investigation of the postmortem cases was initiated, it was thus ascertained that the tomographic *method was good enough* for further evaluation The tomograms obtained from the excised spines in standard positions were then examined against the macerated specimens. The appearances of the normal joints were recorded and any artefacts in the tomographic *depiction sought* The *tomograms* of the excised spines obtained after fluoroscopic positioning were then compared with those after standard positioning and with the specimens so as to discover if the normal tomographic appearances were the same Finally the same kind of comparison was made between the normal appearances and those evident in the living subjects

Results

The tomographic appearances of normal joints obtained from standard post mortem tomograms appeared to be the same as those in the other tomograms

Three aspects will be considered the joint space, the capsular attachments and the subchondral bone The description will not be strictly confined to the tomogram the underlying anatomy if necessary being included

The joint space form This was usually regular (Fig 1 b d e i), although *some exceptions were encountered* The osseous joint surface of the inferior articular process of the L5 vertebra was generally saddle shaped This was reflected in tomograms in a concave shape of the bone towards the joint space the resultant joint space thus being the one most frequently encountered in tomographic planes through the anterior parts of L5—S1 joints (Fig 2 c e) The concavity of the joint surface was less marked or even absent in planes through the posterior parts of these joints (Fig 2d)

A concavity of both osseous joint surfaces was evident in a few joints leading to an ovoid form of the joint space (Fig 2 a) This form appeared in tomograms of the lumbosacral joints as well as of those in higher segments. The typical feature was the smoothness of the curvatures (Fig 2 a) although the curvature of one or both osseous joint surfaces was sometimes slightly irregular without any definite signs of arthrosis in the macerated specimen (Fig 2 b) On the other hand similar irregularities owing to arthrotic remodelling also appeared in some of the joints excluded from the material It thus seemed that

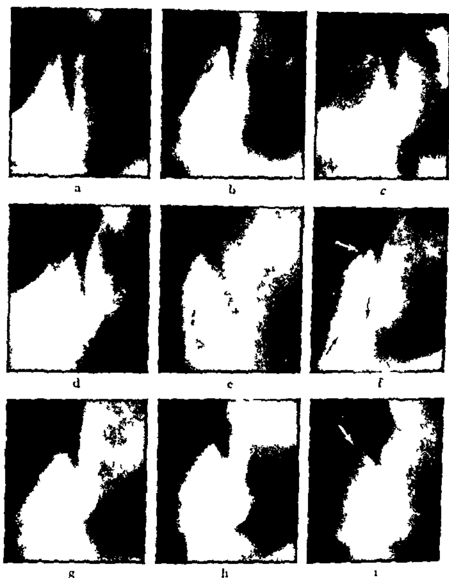


Fig. 1 Original size tomograms of normal lumbar joints of the upper segments, corresponding tomograms of the lower segments appear in fig. [illegible] The variations in joint space, capsular attachments and subchondral bone are illustrated. The black arrows in (f) indicate an area resembling a cyst. The white arrows in (f) and in (i) indicate special apex forms. The tomogram in (e) is obtained from a living subject, the others belong to postmortem cases.

a *smooth ovoid shape should be regarded as a normal variant* and a slightly irregularly ovoid shape not absolutely indicative of arthrosis.

The joint space was only rarely wedge shaped in the way suggested in Fig. 1 a, g, the wedge was always directed downwards. An S shaped joint space was present exceptionally (Fig. 1 h). This form occurred only in some tomograms and never in a whole series. It appeared to be a variant of the normal.

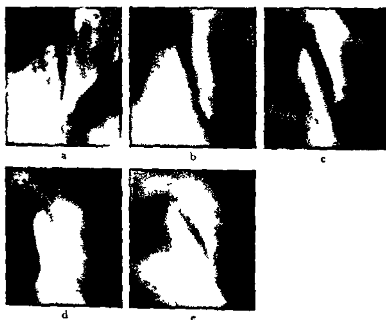


Fig 2 Original size tomograms of normal lumbar joints of the lower segments The variations in joint space capsular attachments and subchondral bone are illustrated as in fig 1 (of upper segment) All tomograms are from postmortem cases

The joint space width Constant geometric magnification is obtained in tomography with the Polytome so that justification exists for measuring the images Joint spaces obviously deviating from the general width were measured with a ruler graduated in millimetres (Figs 1 e 2 b) and found to vary between 1 mm (Fig 1 b) and 4 mm (Figs 1 e 2 b) The same well known pattern as is usually evident in the intervertebral discs was observed The L4—L5 joints were generally the widest the width decreasing as successively higher segments were inspected The width of the L5—S1 joints was likewise often less than that of the L4—L5 joints in the same subject

Reichmann (1971) reported that the joint cartilages posteriorly often have the appearances of fibrous cartilage this type of cartilage is thinner than fully developed hyaline cartilage Such local differences were often evident in tomograms from all segments most strikingly however in the L5—S1 joints. If only a few tomograms are taken in a series and appearances like those in Fig 2 d classed as the only ones technically acceptable a pathologic joint space reduction must not be presumed Supplementary tomography should however if no other signs of abnormality make it certain that a reduced joint space width is present

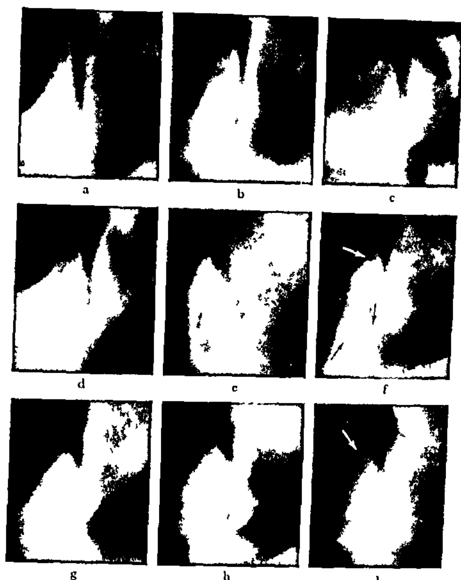


Fig. 1. Original size tomograms of normal lumbar joints of the upper segments; corresponding tomograms of the lower segments appear in fig. 2. The variations in joint space, capsular attachments and subchondral bone are illustrated. The black arrows in (f) indicate an area resembling a cyst. The white arrows in (f) and in (i) indicate special apex forms. The tomogram in (e) is obtained from a living subject, the others belong to postmortem cases.

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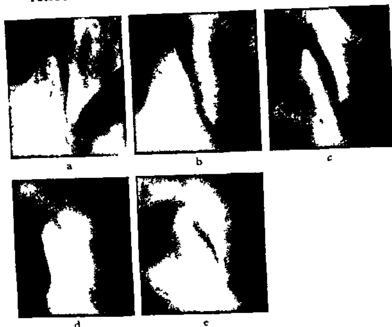


Fig 2 Original size tomograms of normal lumbar joints of the lower segments The variations in joint space capsular attachments and subchondral bone are illustrated as in fig 1 (of upper segment) All tomograms are from postmortem cases

The joint space width Constant geometric magnification is obtained in tomography with the Polytome so that justification exists for measuring the images Joint spaces obviously deviating from the general width were measured with a ruler graduated in millimetres (Figs 1 e, 2 b) and found to vary between 1 mm (Fig 1 b) and 4 mm (Figs 1 e 2 b) The same well known pattern as is usually evident in the intervertebral discs was observed The L4—L5 joints were generally the widest the width decreasing as successively higher segments were inspected The width of the L5—S1 joints was likewise often less than that of the L4—L5 joints in the same subject

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The joint referred to was completely normal and had a much wider joint space in anterior tomographic planes

The width of the upper and lower parts of the joint was naturally minimal in those joints in which one or both of the surfaces were concave The tomograms of some normal joints gave an impression of local reduction in the cartilage (Fig 2 c) This should, however, be looked upon as a normal variant, provided no other signs suggest that cartilage reduction has really occurred

The joint surface area The dimensions of the joint surfaces varied from one subject to another The L1—L2 joints were generally the smallest in one and the same subject, the two lowest segments having the largest joints There were of course exceptions When different individuals were compared, some were found to have larger joints than others The limits for the maximal and minimal height in central sections through the joints were 27 and 17 mm, respectively (Fig 1 a, g)

The joint space orientation An exception as regards the joint orientation in the tomograms is illustrated (Fig 1 e) The posterior parts of the joints were best demonstrated in the 0° or 20° projection The joint surfaces of the upper segments deviated downwards and medially instead of vertically (Fig 1 a, b, c, d) This was evident in several joints of two different individuals, one of them belonging to the group of the living subjects No signs to suggest any cause for this joint surface orientation were apparent in the excised spine

The capsular attachments The only parts of the capsular attachments that could be localized in the tomograms were those in the apical parts of the articular processes The fibrous part of the capsule inserted here runs with the thick flavum ligament and the area of attachment was consequently broad and covered the whole apex

The most common apex form of both superior and inferior articular processes was the smoothly rounded one (Fig 1 d, g) A sharp pointedness of the apex, often modifying the appearances, was not uncommon This was more frequent in the upper than in the lower articular processes but occurred in both Some special apex forms were present at times in the superior articular processes (Fig 1 i) A bone ridge in the lateral part of the capsular attachment at the superior process suggested the presence of an osteophyte Another type appears in Fig 1 c The same lateral ridge was present but was combined with a medial sharpening suggesting the presence of two parallel osteophytes A medial ridge at the border of the joint surface was evident in the third apex form (Fig 1 f) In neither case was there any suggestion that the ridges in question were true osteophytes caused by arthrosis

The subchondral bone The demonstration of the subchondral bone varied

onsiderably A lamella of subchondral cortical bone between the joint cartilage and the trabecular bone of the articular process was usually present However, in some cases more often in the inferior articular processes, the trabecular bone seemed to be separated from the joint cartilage only by a very thin osseous lamina (Fig 2 a inferior articular process) a clearly defined lamella of cortical bone seemed occasionally to be replaced by more diffusely crowded trabecular bone (Fig 2 d)

A lamella of subchondral cortical bone however was usually present its form and thickness varied The thickness was often about the same as the width of the joint space with a tendency of the bone lamella to decrease in thickness towards the apex of the articular process (Figs 1 a c 2 b) Another not so common form was that of an equal thickness of the bone lamella from the base to the apex (Fig 1 b g) The bone lamella could have a thickness clearly larger than that of the joint space regardless of whether a decrease towards the apex was present or not (Fig 1 g) The thickness often increased towards the apex in the superior articular processes of the L5—S1 joints (Fig 2 c)

The tomograms never suggested the presence of subchondral bone cysts resembling those in advanced arthrosis in any case in which the joint space was clearly visible Slight inhomogeneities suggestive of cysts were occasionally evident in eccentric cuts in which the joint space was invisible or represented by spurious contours These tomograms are however unimportant as they fail to demonstrate the joint The cystic areas indicated by the lower arrows were probably due to a spondylolysis situated immediately below (Fig 1 f)

The joints below a spondylolysis Certain variations were evident in joints immediately below a spondylolysis Nothing remarkable was observed in 4 of the 6 joints but in the remaining 2 joints in the L5—S1 segment in one case, obvious deviations from the normal anatomy were present The joint surfaces were somewhat small that of the superior articular process being convex in the transversal plane instead of concave (cf Fig 4 a) The joint surfaces of the inferior articular processes had a corresponding concave form This abnormal curvature of the joint surfaces was difficult to define in the tomograms since it was present in a plane at right angles to the tomographic planes

Reliability and usefulness of the tomographic method The examinations performed in living subjects disclosed that an acceptable representation of the lumbar joints could be obtained by means of hypocycloid tomography at an angle of 48 in spite of the large angle and the large soft tissue mass (cf Fig 1e) the quality sufficed even in the 60 projections obtained at 100 kV Three of the spines tomographed after tomofluoroscopic centering of the tomographic plane were examined together with a 15 cm phantom of paraffin wax substituting



Fig. 3. Original size tomograms with artefacts. The joint surfaces in (a) and (b) are depicted only by means of spurious contours, most of these being double. The anteromedial border of the joint surface of the superior articular process in (c) covers part of the joint space owing to incomplete blurring.

the soft tissue. Better contrast was obtained than in the examinations of the living subjects, the only varying factor in the two types of examination being the view field size. Later tests with different field sizes on one spine and the same phantom confirmed this observation. It was apparent that although an acceptable quality could be obtained when all joints of one side were included in the view field, there was a considerable improvement if the field was reduced so that only half the number of joints were examined each time.

It was obvious from the tomograms of the excised spines that all joints that were sharply depicted were also apparent without artefacts. Those, in the form of spurious contours, appeared only in tomographic planes outside the joints (Fig. 3 a, b), probably masked by the much more intense true contours when the tomographic plane went through the joints. The spurious contours were thus easy to recognize and did not affect the interpretation. The joint surface gave rise to the most intense spurious contours, owing to the great difference in absorption between joint cartilage and compact subchondral bone. Most spurious contours thus imitated joint surfaces in places where such surfaces should not normally appear. As stated by REICHMANN (1972 b) on the nature of spurious contours in hypocycloid tomography, those from the lumbar joints were often double, a fact that made differentiation between true and spurious contours quite simple.

Insufficient blurring rarely occurred. The only type in which the insufficiency could not be immediately recognized appears in Fig. 3 c. The anteromedial border of the joint surface of the superior articular process was edge shaped and projected over the joint space in an adjacent tomographic plane so that an apparent reduction in the space was produced. If more than one tomogram is

Table 2

Failure of tomographic demonstration in the 20° and 50° projections of the postmortem material

Projection	Number of joints not depicted					Total
	L1—L2	L2—L3	L3—L4	L4—L5	L5—S1	
20	0	1	6	9	7	23
50	11	2	1	0	1	15

obtained for each joint as will be suggested, this type of insufficient blurring will not interfere with the interpretation

The statements under this subheading may be summarized by stating that the type of tomography provided excellent reliability with artefacts easily recognizable

Practical performance of the examination The positioning of the patient, the number of tomograms in each series and the determination of the appropriate level for the tomographic plane will be considered As regards the last, part of the result is to be found elsewhere (REICHMANN 1972 a, d) but for the sake of completeness it will also be touched upon

The number of failures in the 20° and 50° projections of the excised spines are listed in Table 2 All failures in this table were due to the fact that the joint surfaces or the capsular attachments were not depicted it being impossible to strike these structures tangentially with the roentgen rays during any part of the exposure in the projection in question The failures were easy to recognize one or more contours being unsharp No joint failed to be outlined in both projections which means that these two standard projections in combination were universally successful in this material The 20° projection was most useful for the upper segments as was the 50° projection for the lower segments It is apparent from Table 2 that if a reduction in the view field size had been undertaken in such a way that the L1—L2 and L2—L3 joints had been represented in one series and the lower joints in another it would have been feasible to have examined the upper joints in the 20° projection and the lower joints in the 50° projection only Supplementary tomograms would then have been required in only 3 out of 99 joints

When the spines were positioned by means of tomofluoroscopy instead of standard projections the most suitable angles of rotation were found to lie between 11° and 59° being remarkably evenly spaced out between 17° and 59° Tomofluoroscopic positioning never increased the variations in the normal tomographic image nor failed in the depiction as described for the standard projections

Table 3

Vertical distances in millimetres between the palpable tips of the spinous processes and the intermediate level used for tomography in the different projections. The numbers refer to the living subjects only. The largest and smallest value measured is listed together with the average for each group. The tomographic plane always lay above the palpable tips.

Projection	Average	Range
0	42	34—49
20	35	31—39
40	20	12—29
50	16	12—22
60	9	4—13

Only in 4 series out of 26 were more than four tomograms taken in the tomographic series of the living subjects. Each single joint was depicted more than once in the larger series. The films in the series of the excised lumbar spines after fluoroscopy usually consisted of only 3 tomograms. (A further tomogram had to be obtained in 2 of the series.) The distance between adjacent tomographic planes in these particular investigations was 4 mm in the living subjects and 5 mm for the spines after fluoroscopy. The distance between adjacent tomographic planes in the main series from the excised spines in standard projections was 3 mm, this distance being regarded as unnecessarily small. However, it was felt that the distance should not exceed 5 mm, since some joints might otherwise escape acceptable representation. The number of 3 to 4 tomographic planes with a distance between adjacent planes of 4 to 5 mm might thus probably be regarded as a minimum for the material. It is possible that further examination of tomograms will indicate that the number is insufficient, this particularly applies to joints with pathologic changes confined to local areas.

The great difficulty in tomography today is the correct siting of the tomographic plane. Two procedures were tested — multisection tomography before single tomography, and tomofluoroscopy, both methods described in detail elsewhere (REICHMANN 1972 a, d). Both proved reliable, the first however appeared to be too time consuming for practical use, so that only tomofluoroscopy seemed to be feasible. The latter method demands equipment not yet in common use, so that a list of the vertical distances between the palpable tips of the spinous processes and the intermediate level of the tomographic planes used in living subjects was prepared. The distance to the table of the tomograph from the spinous processes was subtracted from the distance between the middle tomographic plane and the table as indicated by the tomograph. These subtracted values — average values and range — appear in Table 3. These should prove valuable for 'non fluoroscopic' centering of the tomographic plane.

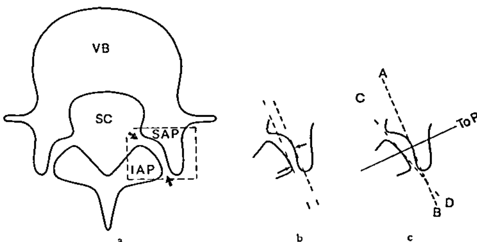


Fig 4 The difference between ordinary radiography and tomography in depicting the lumbar joints A transversal section through a whole vertebral segment appears in (a) Vertebral body VB spinal canal SC The joint (within the rectangle) consists of a superior articular process (SAP) from the vertebra below and an inferior articular process (IAP) from the one above The joint space is indicated by arrows The same joint appears in (b) and (c) as in (a) The joint space in conventional radiography (b) is formed by joint surface parts that are not opposite to each other the SAP forms overprojections that further disturb the interpretation Tomography (c) Opposite points — in the tomographic plane (ToP) — form the joint space of the image Overprojecting structures are blurred

Discussion

Tomography was successful in the postmortem cases examined as well as in the living subjects although the projections in this part of the investigation made supplementary tomography necessary REICHMANN (1972 e), with the same postmortem material has stated that such excellent reliability cannot be obtained with ordinary radiography even after fluoroscopic centering of each intervertebral joint The joint surfaces and the joint space are the most difficult to depict An explanation of this therefore appears desirable

The difference in reliability between conventional radiography and tomography is explained in Fig 4 A transversal section through an intervertebral joint (within rectangle) together with its surroundings appears in Fig 4 a The same joint is reproduced in Fig 4 b c The geometry of ordinary radiography in indicating the joint space is analysed in Fig 4 b The two roentgen rays that are practically parallel strike the two osseous joint surfaces tangentially at the points marked by arrows so that a joint space limited by sharp contours will appear in the roentgenogram Both osseous joint surfaces are curved although not to the same degree that of the superior articular process very often having

a more marked curvature (REICHMANN 1972 c) The parallel rays can therefore only exceptionally strike the joint surfaces tangentially at points that are opposed It often happens, however, that these points are situated so far from each other in the direction of the roentgen rays that false information is presented as to the true width of the joint space False impression of a reduction in the joint space width might be the final result (Fig 4 b)

The tomographic demonstration of the same joint appears in Fig 4 c Since every structure is registered during that part of the tomographic exposure when it is struck by tangential roentgen rays (DE WAARD 1938, REICHMANN 1972 c), it is evident that the surface of the superior articular process is reproduced when the rays are directed from A to B This roentgen direction cannot record the inferior articular process since the site where such rays strike the joint surface tangentially is too far from the tomographic plane This joint surface is depicted when the rays are directed from C to D, opposite joint surface points are thus registered The incongruity of the osseous joint surfaces is in fact compensated for by the tomographic sweep, the larger the sweep i e the greater the tomographic angle, the larger the capacity to compensate for joint surface incongruities

In summary, the advantage of tomography in the examination of the lumbar intervertebral joints is explained not only by the fact that detail situated outside the tomographic plane is blurred but that roentgen rays in continually changing their direction make it possible to demonstrate the osseous joint surfaces at the same level even if they are incongruous The first reason for using tomography, regardless of object is universally recognized, but the latter seems to be largely unknown Still the distinction is important to bear in mind, since, as demonstrated by REICHMANN (1972 c) a high degree of blurring may be obtained even if the tomographic angle be relatively small For this tomographic task, however, a large tomographic angle other than for producing a high degree of blurring is necessary

Multidirectional tomography was chosen as against linear tomography, as the latter cannot demonstrate both the joint space and the capsular attachments satisfactorily This was confirmed by test tomography of an excised spine with different tomographic angles and directions of linear movement Hypocycloid tomography was used in the method presented as the spurious contours present in all current types of tomography are then relatively easy to recognize (REICHMANN 1972 b)

The selection of the appropriate level of the tomographic plane is often difficult, so that tomography is usually secondary to conventional radiography The level of the tomographic plane may however rapidly be determined by means of tomofluoroscopy (REICHMANN 1972 d) As regards the Polytome, this type of

centering is possible today if its standard equipment for television fluoroscopy be used Considerable improvement in fluoroscopic equipment may be expected and lead to simplification in tomofluoro copy It is therefore highly probable that fluoroscopy will become a routine method within relatively few years

Certain variations in the tomographic image of normal joints have been described in this paper The *spectrum of normal* variations in the tomogram corresponds to variations in the anatomy such as tho e described by REICH MANN (1971) The *abnormal* joint surface anatomy in two joints below a pondylolysis is in accordance with the observations of BROCHER (1966) that dysplasias *may occur in such joints* Several normal forms have suggested the pre ence of pathologic conditions and so it eems probable that the demonstration *of joint changes when present will demand either one* definite sign or if le s developed several

Acknowledgements

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SUMMARY

Hypocycloid tomography at an angle of 48 was investigated to determine whether it *furnished more reliable information than conventional radiography* The recommended procedures described in detail produced tomograms of high reliability and quality It is su ested that the lumbar joints should be examined by tomography without previous ordinary radiography

ZUSAMMENFASSUNG

Die hypocycloide Tomographie bei einem Winkel von 48 wurde geprüft, um festzustellen ob diese zuverlässigere Information als konventionelle Radiographie verschafft Die empfoh lenen Verfahren die im einzelnen beschrieben werden geben Tomogramme von hoher Zuver lässigkeit und Qualität Es wird vorgeschlagen dass die Lumbalgelenke mit der Tomo graphie ohne vorhergehende gewöhnliche Radiographie untersucht *werden sollten*

RÉSUMÉ

L auteur a étudié la tomo raphie hypocycloïdale avec un angle de 48 *pour savoir si* elle donne une information plus fidèle que la radiographie simple Les techniques recom mandées sont décrites en détail et ont donné des tomographies d une grande fidélité et d une grande qualité L auteur *pense que* les articulations lombaires devraient être exami nées par tomographie sans radiographie simple préalable

REFERENCES

BADGLEY C The articular facets in relation to low back pain and sciatic radiation J Bone Jt Surg 23 (1941) 481

BUSI H Zur Darstellung der praesakralen Wirbelgelenke und der praesakralen Interartikularportion im schrägen Strahlengang Fortschr Röntgenstr 99 (1963) 211

BROCHER J E W Die Wirbelsäulenleiden und ihre Differentialdiagnose Georg Thieme Verlag Stuttgart 1966

CALLAN P S FRIEDMAN I M J and CONNELLY T P Degenerative joint disease of the lumbar spine in coal miners A clinical and x ray study Arthr and Rheum 9 (1966), 693

DEWAARD R H On a fundamental property of planigraphic image formation Acta radiol 19 (1938) 165

DITTMAR O (a) Halbseitliche Aufnahme des Lendenwirbel Kreuzbein Abschnittes Fortschr Röntgenstr 39 (1929) 864

— (b) Halbseitliche Aufnahme des Lendenwirbel Kreuzbein Abschnittes Fortschr Röntgenstr 40 (1929) 99

ERDMANN H Personal communication (1967)

FRIEDMAN M M FISCHER F J and VAN DEMARK R E Lumbosacral roentgenograms of one hundred soldiers Amer J Roentgenol 55 (1946) 292

GHORMLEY R K and KIRKLIN B R The oblique view for demonstration of the articular facets in lumbosacral backache and sciatic pain Amer J Roentgenol 31 (1934) 173

GÜNTZ E Die Erkrankungen der Zwischenwirbelgelenke Arch orthop Unfall Chir 34 (1933/34) 333

HADLEY L A Anatomico roentgenographic studies of the posterior spinal articulations Amer J Roentgenol 86 (1961) 270

HORWÁTH F und MASSÁNYI L Über diagnostische Schwierigkeiten verursachende Formveränderungen der Wirbelgelenkfortsätze Fortschr Röntgenstr 97 (1962) 757

HORWITZ T and SMITH R M An anatomical pathological and roentgenological study of the intervertebral joints of the lumbar spine and of the sacroiliac joint Amer J Roentgenol 43 (1940) 173

HUBENY M J The oblique projection in the examination of the lumbar spine Radiology 16 (1931) 720

INGELMARK B E Function of and pathological changes in the spinal joints Acta anat (1959) Suppl No 36 p 12

LANGE H Die Wirbelgelenke Ferdinand Enke Verlag Stuttgart 1936

LAWRENCE J S SHARP J BALL J and BIER F Rheumatoid arthritis of the lumbar spine Ann rheum Dis 23 (1964) 205

LEUBNER H Die Arthritis deformans der kleinen Wirbelgelenke Z orthop Chir 65 (1936) 42

LEWIN T Osteoarthritis in lumbar synovial joints Acta orthop scand (1964) Suppl No 73

LYON E Spondylosis deformans Arthrosis deformans der kleinen Wirbelgelenke und Nervensystem Fortschr Röntgenstr 48 (1933) 46

MORTON S A Value of the oblique view in the radiographic examination of the lumbar spine Radiology 29 (1937) 568

OPPENHEIMER A Diseases of the apophyseal articulations J Bone Jt Surg 20 (1938) 285

PÁLVÖLGYI R Über eine neue Methode zur Anfertigung zervikaler Foramen und lumbaler Kleingelenkaufnahmen Röntgen Bl 21 (1968) 116

PFEIL E Stellungsvarianten der Gelenkfortsatze am Lenden Kreuzbein Übergang Zbl Chir 93 (1968) 10

PHEASANT H C and SWENSON P C The lumbosacral region A correlation of the roentgenographic and anatomical observations J Bone Jt Surg 24 (1942) 299

PUTTI V New conceptions in the pathogenesis of sciatic pain Lancet II (1927) 53

REICHMANN S The postnatal development of form and orientation of the lumbar intervertebral joint surfaces Z Anat Entwickl Gesch 133 (1971) 102

— (a) Einfache Hilfsmittel fur die Rontgendiagnostik der lumbalen Intervertebralgelenke *To be published in Rontgen Bl* (1972)

— (b) Development of spurious contours of spherical and cylindrical objects in tomography Acta radiol Diagnosis 12 (1972) 317

— (c) Modified theory of the development of tomographic blurring Acta radiol Diagnosis 12 (1972) 457

— (d) Tomofluoroscopy and its application in the examination of the lumbar intervertebral joints Acta radiol Diagnosis 12 (1972) 579

— (e) Radiography of the lumbar intervertebral joints. To be published in Acta radiol Diagnosis

REINHARDT K Die Anatomie und Pathologie der kleinen Wirbelgelenke im Rontgenbild Radiol diagn 4 (1963) 665

SAGER P Spondylosis cervicalis A pathological and osteoarchaeological study Munksgaard Copenhagen 1969

SCHMORL G und JUNGHANNS H Die gesunde und die kranke Wirbelsaule in Rontgenbild und Klinik. Georg Thieme Verlag Stuttgart 1968

SCOTT W Low back pain resulting from arthritis and subluxations of the apophyseal joints and fractures of the lumbar spine Amer J Roentgenol 48 (1942) 491

WIEDENMANN L Vergleichende Untersuchungen uber Bildqualitat und Dosisbedarf bei Simultan und Einzelschichtaufnahmen Fortschr Rontgenstr 89 (1958) 613

FROM THE DEPARTMENTS OF RADIOLOGY AND SURGERY, ST THOMAS' HOSPITAL, LONDON, ENGLAND

INTERNAL ILIAC VEIN THROMBOSIS

by

M LEA THOMAS and N L BROWSE

It is a frequently made observation in textbooks and original reports that the calf veins and the pelvic veins are the two most common sources of pulmonary emboli There is no doubt that the calf veins are the most common source of emboli, in a recent investigation (BROWSE et coll 1969) of 50 patients who had just suffered an embolus, 35 had thrombus in the calf or ilio femoral segment, but the importance of the true pelvic veins is open to doubt Confusion begins because many do not appreciate that there are two quite different anatomic types of vein in the pelvis First, there are the large, long, relatively straight common and external iliac veins which form an uninterrupted tube, continuous with the common femoral and superficial femoral veins in the thigh and which can be considered as one vein This tube, which is often 80 cm long and 2 to 3 cm in diameter and may contain a thrombus large enough to totally obstruct the pulmonary artery should it break free, is best called the ilio femoral segment (MAVOR & GALLOWAY 1967) The second group of veins is the multitude of small vessels which drain the viscera within the pelvis, and the muscles of the pelvis and buttock These veins converge in a small area to form the short internal iliac vein

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To most clinicians the expression pelvic vein thrombosis implies thrombosis in the vessels in the floor of the pelvis that is to say the internal iliac system, and it is often said that thrombosis in these veins is particularly common after pelvic surgery such as hysterectomy, anterior resection of the rectum, prostatectomy and bladder operations It has become our impression over the years that internal iliac vein thrombosis is rare when compared to the incidence of ilio-femoral vein thrombosis even in patients who have had pelvic operations consequently we decided to assess its true incidence This immediately presented a number of problems because the internal iliac venous system is not usually demonstrated with the common methods of investigation such as ascending phlebography or the [1] I fibrinogen uptake test The only investigation which will usually display most of the tributaries of the internal iliac vein, as well as its stem, is pertrochanteric intra osseous phlebography This is an uncommon method because it is usually possible to demonstrate the clinically important ilio femoral segment with a peripheral or femoral vein injection We therefore examined those intra osseous phlebograms which displayed the internal iliac veins fully All of these contained thrombus in some part of the internal or external pelvic venous system so that these are a highly selected group of patients yet we believe the evidence they contain is sufficient to suggest that primary thrombosis in the internal iliac veins is rare

Phlebography

Three methods of phlebography will display the internal iliac veins (1) Percutaneous femoral (2) pertrochanteric intra osseous and (3) combined femoral and intra osseous pelvic phlebography

All methods are best performed with a 35 5 cm × 35 5 cm AOT serial changer and television monitoring At the end of the examination the contrast medium is cleared from the venous system by flushing with 0 9 per cent saline

Percutaneous femoral pelvic phlebography (1) A 35 5 × 35 5 cm p a film of the pelvis is taken for checking exposure and centering The field extends from the ischial tuberosities to the body of the 4th lumbar vertebra (2) With the patient in the supine position and using local anaesthesia both femoral veins are punctured with metal cannulae (SHELDON 1964) which are then threaded a short distance up the veins to prevent extravasation of the contrast medium during injection (3) Test injections of 5 ml of contrast medium are observed with the television to ensure that the cannulae are within the lumen of the veins (4) Each cannula is connected by a polythene tube to a 50 ml syringe containing 50 ml of contrast medium We use sodium iothalamate 70 % (Conray 120) which combines a low viscosity with high radiation absorption (5) In

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by

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It is a frequently made observation in textbooks and original reports that the calf veins and the pelvic veins are the two most common sources of pulmonary emboli There is no doubt that the calf veins are the most common source of emboli in a recent investigation (BROWSE et coll 1969) of 50 patients who had just suffered an embolus, 35 had thrombus in the calf or ilio femoral segment but the importance of the true pelvic veins is open to doubt Confusion begins because many do not appreciate that there are two quite different anatomic types of vein in the pelvis First, there are the large, long, relatively straight common and external iliac veins which form an uninterrupted tube, continuous with the common femoral and superficial femoral veins in the thigh and which can be considered as one vein This tube, which is often 80 cm long and 2 to 3 cm in diameter and may contain a thrombus large enough to totally obstruct the pulmonary artery should it break free, is best called the *ilio femoral segment* (MAYOR & GALLOWAY 1967) The second group of veins is the multitude of small vessels which drain the viscera within the pelvis, and the muscles of the pelvis and buttock These veins converge in a small area to form the short internal iliac vein

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Fig 1 Normal pelvic phlebogram Bilateral pertrochanteric intra-osseous injections Supine (a) and prone (b) position The former position permits much better filling of the internal iliac vein and its tributaries

or external iliac vein thrombus which did not extend back into the tributaries in the pelvis i e it could not have extended from primary thrombus in tributaries (3) Primary thrombus in the internal iliac vein tributaries thrombus separate from any type of thrombus in the internal iliac vein stem or continuous with a previously classified primary thrombus in the internal iliac vein stem (4) Secondary thrombus in the internal iliac vein tributaries thrombus continuous with a previously classified secondary thrombus in the internal iliac vein stem

Many criticisms could be made of this method of classification but in practice we always agreed on the definition of the type of the thrombus and had no difficulty in coming to this agreement The most debatable point is whether a film of completely occluded ilio-femoral segment and just the upper part of the internal iliac vein blocked demonstrates a primary thrombosis in the former or the latter In our experience of many hundreds of phlebographies we have only once seen a thrombus growing from the mouth of the internal iliac vein up into the common iliac vein whereas we have seen many examples of thrombus known to have begun in the thigh, extend up the leg into the abdomen and then block off the upper part of the internal iliac vein Thus we classified as primary stem vein occlusion those in which the tributaries of the internal iliac vein were normal and there was extensive ilio-femoral thrombosis. This conclusion fits our clinical experience Those thrombi defined as secondary tributary thrombus might however be a primary internal vein thrombosis The pres-

tions are made simultaneously by hand by two operators and 10 films are taken at 1 second intervals The injection and exposure are started at the same time A Valsalva manoeuvre is performed by the patient in the middle of the series to fill the internal iliac veins as far down as the first competent valve

Pertrochanteric intra osseous pelvic phlebography (1) A film is taken as for femoral pelvic phlebography (2) With the patient under general anaesthesia in the supine position, two intra osseous cannulae are introduced into the lateral aspects of both greater trochanters under television control Their positions are controlled by the injection of small quantities of contrast medium (3) Each cannula is connected through a polythene tube to separate metal syringes containing 50 ml of sodium iothalamate 70 % (4) Simultaneous injections are made, using two pressure injectors set to deliver the contrast medium at a rate of 10 ml/s A Y connection with one pump is not satisfactory as the contrast medium tends to go into the cannula presenting the least resistance to flow (5) Ten films are taken, one per second The first exposure is made half way through the injection

Combined femoral and intra osseous pelvic phlebography Fifty ml of contrast medium are injected by hand into the femoral vein on one side and 50 ml of contrast injected into the greater trochanter using a pressure pump on the other The femoral vein injection and exposure are started half way through the intra osseous injection Ten films are taken and a Valsalva manoeuvre is mimicked by the anaesthetist producing a high intra pleural pressure half way through the injection into the femoral vein

Definitions

All phlebograms were examined by both authors to determine the anatomy of the pelvic veins and the site and incidence of thrombosis

Site of thrombosis The veins were divided into four segments the common iliac external iliac, internal iliac stem, and internal iliac tributaries, using the usual anatomy textbook definitions of those vessels

Type of thrombus The thrombus was classified by its appearance into primary thrombus and secondary thrombus using the following criteria (1) *Primary thrombus in the internal iliac vein stem* thrombus in the internal iliac vein stem which was quite separate from any thrombus in the common or external iliac veins Thrombus in the stem continuous with primary thrombus in the tributaries was classified as primary stem thrombus (2) Secondary thrombus in the internal iliac vein stem thrombus continuous with an extensive common

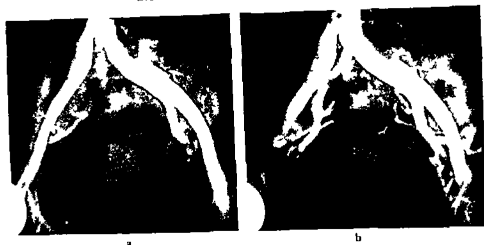


Fig 3 Right internal iliac vein draining into left common iliac vein bilateral femoral vein injections a) Patient breathing normally b) Patient performing a Valsalva manoeuvre which has filled a few tributaries of the internal iliac vein on the left but not sufficient for the diagnosis of thrombosis

vessels are given in Fig 2 The stem of the internal iliac vein is usually 3 to 7 cm long and about 1 cm wide It usually joins with the external iliac vein in front of the sacro-iliac joint but this junction is very variable, the left vein may even drain to the right side and vice versa (Fig 3) The main trunk is formed from five groups of veins On the medial side are the lateral sacral veins draining the sacrum Below these are a whole cluster of small veins coming from a plexus on the floor of the pelvis which receives veins from the rectum, prostate bladder vagina and uterus Inferiorly are the obturator veins infero laterally the inferior gluteal veins and supero laterally the superior gluteal veins These veins may be single double or multiple The simplest method of orientating a film is to remember that the vein which appears to run from the centre of the head of the femur to the internal iliac vein is usually the inferior gluteal vein

In the presence of venous occlusion many other veins will be displayed These are either enlarged versions of the normal anatomy or extra unnamed veins Two important collateral vessels that are always seen in inferior vena cava obstruction are the ascending lumbar veins and the ovarian veins both easily distinguished from their site and direction (FLETCHER & LEA THOMAS 1968)

Incidence of thrombosis The phlebograms in diagram form, of 24 patients who had thrombus in some part of their pelvic venous system and in whom adequate films were obtained of the internal and external iliac systems on both sides are shown in Fig 4 Most had *thrombus* in the common or external iliac

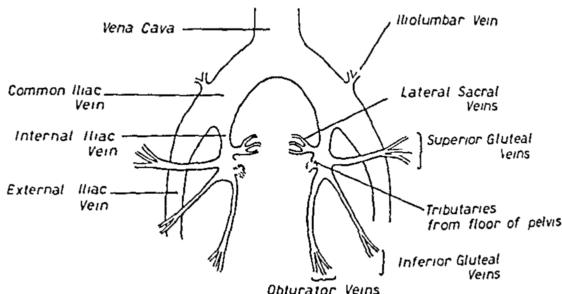


Fig 2 Anatomy of the tributaries of the internal iliac vein The inferior gluteal vein usually appears to cross the centre to the head of the femur

ence of thrombus was diagnosed according to previously described criteria (DeWeese & Rogoff 1963, Browse et coll 1967)

Results

In the two years between the middle of 1968 and the middle of 1970 a large number of films were taken of the ilio femoral segments and 40 intra osseous iliac phlebographies were performed but when they were closely examined only 24 sets of films displayed the tributaries of the internal iliac veins well enough to meet the requirements of this investigation These films were obtained from 13 females and 11 males The combined procedure, intra osseous injection on one side and intravenous injection on the other, was used in 15 cases, bilateral intra osseous injections were used in 6 and bilateral femoral vein injections in 3 As the latter procedure is the most common method used for investigating the pelvic veins the small number of suitable cases indicates its inadequacy as a means of displaying the small pelvic veins It is adequate when combined with an intra osseous injection if the femoral vein on the side of the latter is occluded because the contrast medium from the intra osseous injection crosses the floor of the pelvis and so fills both sets of tributaries

Anatomy A bilateral pertrochanteric intra osseous phlebogram, taken in the supine and prone positions, is shown in Fig 1 The names of the main

Table

Distribution of the thrombus in the various anatomic segments and its nature

Vein and type of thrombosis	Number of veins containing thrombus (48 sets of veins)			
	Right	Left	Total	Per cent
Common iliac (primary or secondary)	8	16	24	50
External iliac (primary or secondary)	8	19	27	56
Internal iliac stem (secondary)	5	12	17	35
Internal iliac tributaries (secondary)	2	4	6	12
Internal iliac stem (primary)	0	1	1	2
Internal iliac tributaries (primary)	1	5	6	12

(*[illegible] of the 48 internal iliac veins contained thrombus 8 had more than one type*)

In only three cases were the veins above the internal iliac vein clear so that the thrombus had it broken free could have reached the lung In one case there was loose thrombus in the tributaries on the right and no other thrombosis on that side although there was extensive ilio femoral thrombosis on the left In another case (Fig 7) there was fresh thrombus in the tributaries on the left and an external iliac thrombosis on the same side but the left internal stem and common iliac vein was patent In the only instance of a primary stem thrombosis the thrombus was adherent and therefore safe but there was no obstruction above it

Thus in 24 patients only 3 internal iliac veins contained thrombus that could have reached the lungs were it to break free In one of these the thrombus was firmly adherent and in the other it was so small that it would probably not have produced pulmonary symptoms The other three patients with primary thrombus in the tributaries had blocked veins between them and the heart (Fig 8)

No adherent thrombus was seen in the internal iliac vein tributaries but this may be an artefact because it is probably impossible to detect an unfilled vein in the midst of the mesh of pelvic floor veins present in the phlebogram

The thrombus was completely adherent in all 17 cases of secondary internal iliac thrombosis even though all these patients were examined following a clinical diagnosis of recent acute thrombosis In 13 cases it was continuous with an adherent common external vein thrombus

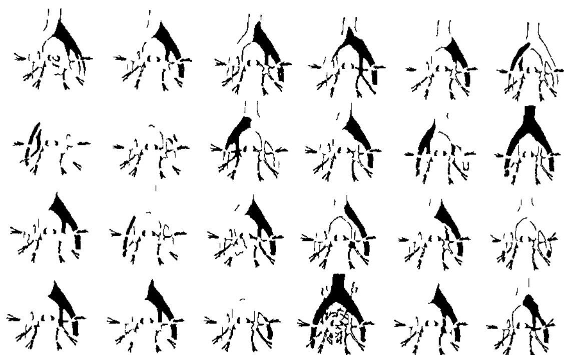


Fig. 4. Diagrams of the phlebograms. The black areas indicate thrombus.

veins, in fact one or other of these veins was usually completely occluded because this was, of course, the main indication for performing an intra osseous examination.

Thrombus was present in the left half of the pelvis in 15 patients (62 per cent), in the right side in 5 (21 per cent) and in both sides in 4 (17 per cent). The left sided preponderance of common and external iliac vein thrombosis has been commented on by numerous authors (COCKETT & LEA THOMAS 1965).

The distribution of the thrombus in the various anatomic segments and its nature — primary or secondary — are shown in the Table. Of the 48 internal iliac veins 22 contained thrombus. In only 2 of these was the thrombus solely confined to the internal iliac vein, the other 20 also had thrombus in the common or external iliac veins.

In 8 patients the thrombus was in the common or external iliac veins alone and 16 sides had no thrombus whatsoever.

An analysis of the 22 sides containing internal iliac vein thrombus shows that it was confined to the stem on 10 and was by our criteria a secondary thrombosis in all cases (Fig. 5). On 8 sides there was combined stem and tributary thrombus (6 secondary thrombus in stem with secondary thrombus in tributaries, 1 secondary and 1 primary thrombus in stem with primary thrombus in tributaries) (Fig. 6) and on 4 sides thrombus in the tributaries alone (all primary thrombus).



Fig 7 Fre h non adherent thrombus in the left inferior gl teal vein The left common il ac vein is patent but there is a thrombus in the left external l ac and femoral eins The thrombus in the internal iliac system could have reacl ed the heart had it broken free



Fig 8 Fresh non adherent thrombus in the obturator vein This thrombus could not have become a pulmonary embolus because the stem of the left internal iliac vein is blocked by thrombus propagating down from a complete ilio-femoral occlusion

incidence of internal iliac vein thrombosis Post mortem investigations by SEVITT & GALLAGHER (1961) on a highly selected group of patients in that they were mostly elderly people who had all died and had thrombosis somewhere in their limbs revealed an incidence of thrombosis in the small veins of the pelvis in 7 of 81 patients (8 6 per cent) or 9 of 162 legs (5 5 per cent) It is likely that our patients would have had a higher incidence of internal iliac vein thrombosis in the pelvic veins because most of theirs had thrombosis in the legs only Thus their post mortem figures probably do not differ greatly from the figures we have presented

Many authors have commented on the importance or otherwise of internal iliac vein thrombosis but to our knowledge there has been no data previously



Fig. 5. A completely occluded left ilio-femoral segment with non-adherent thrombus propagating down the left internal iliac vein. The origins of a number of tributaries are also blocked.



Fig. 6. A completely occluded left ilio-femoral segment with adherent secondary thrombus occluding the left internal iliac vein and the terminations of many of its tributaries so that a mesh of fine collateral vessels has developed.

Discussion

It is apparent that there are two distinct and dissimilar sets of pelvic veins and the collective term "pelvic vein thrombosis" would be best discarded. It would be much better to talk of the two sets of veins independently, (1) the common and external iliac venous system or better the "ilio-femoral segment", meaning the large straight uninterrupted tube that runs from the knee to the beginning of the vena cava, and (2) the true internal iliac vein, its stem and tributaries. The ilio-femoral segment is a common source of lethal emboli whereas primary internal iliac vein thrombosis seems to be rare, 6 patients out of 24 very high risk subjects (25 per cent). The size of the thrombus in these small veins makes it unlikely to be a cause of serious emboli or even infarction, a point made by ASCHOFF in 1924. There is very little published data for the



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Many authors have commented on the importance or otherwise of internal iliac vein thrombosis but to our knowledge there has been no data previously

published about its incidence in life. In this analysis we have selected films which have had some thrombosis in the veins within the pelvis, a group that one would expect to have the highest incidence of thrombosis in the internal iliac veins. As only one of the 24 patients with internal iliac thrombosis had a primary thrombosis in the internal iliac vein stem and five in the tributaries, a total incidence of 25 per cent in a high risk group, it is reasonable to say that internal iliac vein thrombosis is uncommon. If veins rather than patients be considered the incidence is only 12 per cent. We have not had the opportunity of examining the internal iliac veins in patients with thrombosis confined to the calf because the investigations would not be justifiable, but it is likely that internal iliac thrombosis is much less common in this group when compared to those with ilio-femoral thrombosis. If it is argued that only those cases of thrombus in the internal iliac stem alone plus ilio-femoral thrombosis be examples of secondary thrombosis and that all cases with thrombus in the tributaries be examples of primary thrombi then 12 of the 48 sides (25 per cent) had a primary thrombosis. Even with this definition the overall incidence remains low.

We have had no complications from the radiologic examinations. They must all be carried out under sterile conditions and the venous system must always be flushed with 0.9 per cent saline to clear the contrast medium from the veins to prevent intimal irritation and thrombosis afterwards. Intra-osseous phlebography is potentially more hazardous as it could produce osteomyelitis. For this reason we prefer to use femoral vein injections whenever possible although we have never had a case of bone or soft tissue infection resulting from intra-osseous phlebography. Sometimes the injection site is a little tender if the contrast medium leaks from the bone into the soft tissues.

The cannula one of us (Lea Thomas 1969) has devised has a three-faceted drill tip for easier introduction, is larger in length and bore than the standard bone marrow needle and allows a firmer hand grip. This makes the examination easy to perform and produces better filling of the veins. The disadvantage of intra-osseous phlebography is that, being painful, it requires a general anaesthesia, which introduces a further hazard in patients with severe pulmonary embolism, but this is usually outweighed by the tremendous advantage of being able to obtain a diagnostic phlebogram of all the pelvic veins in almost all instances.

There is a vast network of veins around the bladder, rectum and vagina which are impossible to demonstrate fully by phlebography unless they are acting as collaterals to an occlusion of the iliac veins and inferior vena cava. Small thrombi may be present in these veins and not show up in the phlebogram. In practice this does not appear to matter and careful scrutiny of the internal

iliac vein tributaries will often show the end of a small thrombus jutting into a patent vein which indicates a tributary occluded by thrombus

Taking of a series of films usually excludes errors of interpretation due to streaming and failure of mixing of the contrast medium with the blood Not every tributary will be displayed on a single film so the whole series must always be examined A series of films may also give some indication of the direction of blood flow

All phlebographies should be carried out in the supine position as in this position the contrast medium being heavier than blood fills the dependent internal iliac system (Fig 1)

The main advantage of percutaneous pelvic phlebography is that it can be done with a local anaesthetic and the Valsalva manoeuvre is easier with a conscious patient Its main disadvantage is that it only demonstrates the internal iliac veins down as far as the first competent valve and the site of this varies from patient to patient and between sides (Fig 2)

We conclude therefore by suggesting that thrombosis in the internal iliac vein or its tributaries is a relatively uncommon condition and that the circumstances whereby such thrombus might give rise to pulmonary emboli are rare We suggest that the non specific term pelvic vein thrombosis be discarded and that the conduits which carry blood from the limbs, the common and external iliac veins be called the ilio-femoral segment and the set of vessels which drain the viscera of the pelvis be called the internal iliac system

SUMMARY

In an attempt to define the incidence of internal iliac vein thrombosis during life twenty four sets of phlebograms have been analysed All patients had thrombosis somewhere in the pelvis The incidence of primary internal iliac vein thrombosis in this selected and high risk group was 25 per cent In only 3 patients were the veins above the internal iliac vein tributaries patent Thus primary internal iliac vein thrombosis is uncommon and embolism from these veins rare

ZUSAMMENFASSUNG

In einem Versuch das Vorkommen der Thrombose der Vena iliaca interna wahrend des Lebens festzustellen wurden 24 Serien von Phlebogrammen analysiert Alle Patienten hatten Thrombosen irgendwo im Becken Das Vorkommen einer primaren Thrombose der Vena iliaca interna in dieser ausgewahlten Gruppe mit einem hohen Risiko betrug 25 Prozent In nur 3 Patienten waren die Venen oberhalb der Zuflusse der Vena iliaca interna offen Die primare Thrombose der Vena iliaca interna ist somit ungewohnlich und eine Embolie von diesen Venen selten

RÉSUMÉ

Les auteurs ont analyse 24 series de phlebogrammes pour essayer de definir la frequence de la thrombose de la veine iliaque interne pendant la vie Tous les malades avaient une thrombose quelque part dans le bassin La frequence de la thrombose primitive de la veine iliaque interne dans ce groupe selectionne a haut risque etait de 25 pour cent Les veines situees au dessus des affluents des veines iliaques internes n etaient permeables que chez 3 malades La thrombose primitive de la veine iliaque interne est donc peu frequente et les embolies a partir de ces veines sont rares

REFERENCES

ASCHOFF A Lecture in general pathology New York 1924

BROWSE N L LEA THOMAS M and SOLAN M J Management of the source of pulmonary emboli the value of phlebography Brit med J 4 (1967) 596

— — — and YOUNG A E Prevention of recurrent pulmonary embolism Brit med J 3 (1969) 382

COCKETT F B and LEA THOMAS M The iliac compression syndrome Brit J Surg 52 (1965) 816

DEWEESE J A and ROGOFF S M Phlebographic pattern of acute deep venous thrombosis of leg Surgery 53 (1963) 99

FLETCHER E W L and LEA THOMAS M Chronic post thrombotic obstruction of inferior vena cava investigated by cavography Amer J Roentgenol *102* (1968) 363

LEA THOMAS M Improved intraosseous phlebography cannula Brit J Radiol 42 (1969) 395

MAVOR G L and GALLOWAY J M D The ilio femoral venous segment as a source of pulmonary emboli Lancet 1967 I p 871

SEVITT S and GALLAGHER N Venous thrombosis and pulmonary embolism A clinico pathological study in injured and burned patients Brit J Surg 48 (1961) 475

SHELDON P Percutaneous cannulation of carotid artery Brit J Radiol 37 (1964) 526

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ROENTGENOLOGIC METHODS IN EXAMINATION OF THE LARYNX

Comparative phantom investigations in the frontal projections

by

ANDERS HEMMINGSSON

The roentgenologic demonstration of the larynx in the frontal projection is usually rendered unsatisfactory by masking by the cervical spine. Different methods have been employed in attempts to overcome this difficulty, e.g. examinations with positive contrast media (JACKSON 1918, POWERS *et coll.* 1957, and others), and ordinary radiography with a high potential technique (STEPHANIE 1929, BEIQUE & ROTENBERG 1965, MAGUIRE et coll. 1965, MAGUIRE 1966, THORNBURY & LATOURETTE 1967, among others). Theoretic calculations on a cervical model have also indicated that a high tube potential corresponding to monoenergetic radiation with photon energies of 150 to 200 keV is advantageous in ordinary frontal radiography of the larynx (HEMMINGSSON & LUNDQVIST 1972).

Tomography (LEBORGNE 1936) has been used to reduce the reproduction of bone structures, a method of examination that has also been combined with the administration of contrast media (BRAUER 1955). Frontal tomography of the larynx is associated with blur from the cervical spine as a result of which at a

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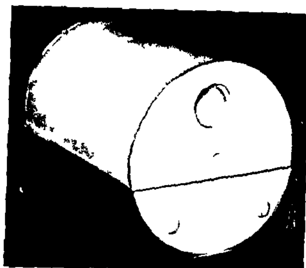


Fig. 1. The cervical phantom.

linear exposure angle of 55° the effective separation between the sections is greater than 1 cm (ARDRAN & LAWS ROBERTS 1965); these authors failed however to give the tube potential at which this is valid. The section thickness decreases however with reduced radiographic contrast (WILLNER 1956 and VUORINEN 1959). It is possible therefore that the interfering blur from the cervical spine may be reduced by increasing the tube potential and the filtration of the beam and so produce a rapid decrease in the attenuation in bone tissue and improvement in the diagnostic possibilities. The importance of the beam energy in frontal laryngeal tomography appears however not to have been discussed previously.

Phantom investigations were performed in an attempt to determine whether any diagnostic advantages appeared at different potentials and filtrations in frontal tomography of the larynx. Theoretic calculations (HEMMINGSSON & LUNDQVIST 1972) were correlated with findings at ordinary radiography. In addition, four methods of examination, viz. ordinary radiography and tomography with and without contrast media were compared in phantom investigations to find out which was the better diagnostic method and to determine the potential that should be employed.

The criteria for the best method were as follows. It should allow evaluation of the entire larynx in the sagittal plane assessed by using the smallest visible soft tissue objects as indicators. The exposure time should be relatively short, preferably less than 0.5 s since the walls of the larynx do not remain completely immobile during phonation; this involves a risk of unsharpness due to movement. A further requirement is that the dose of radiation should be as low as possible. Other methods for reducing the interfering image of the skeletal structures in

Table 1

Experimental conditions in the phantom investigations

	Ordinary radiography			Tomography	
	Without contrast medium		With contrast medium	Without contrast medium	With contrast medium
	50—200 kV	1 17—1 33 MeV (^{60}Co)			
Focal spot	1 2 mm	2 cm	1 2 mm	1 2 mm	1 2 mm
Inherent filtration	1 8 mm Al	—	1 8 mm Al	1 8 mm Al	1 8 mm Al
Film focus distance	140 cm	198 cm	140 cm	140 cm	140 cm
Object film distance	20 cm	7—8 cm	20 cm	20 cm	20 cm
Grid ratio	7	—	7	7	7
Film	Kodak RP X Omat Nos 151261 and 351222 Med chrome$_p$ No 24920636	3 M Sigma No R 9501—9	Kodak RP X Omat No 351222	Kodak RP X Omat No 351222	Kodak RP X Omat No 351222
Intensifying screens	Ruby (Siemens)	0 10 and 0 15 mm lead (Siemens)	Ruby (Siemens)	Multisection cassette (Siemens) Ruby (Siemens) Cronex (Du Pont)	Multisection cassette (Siemens) Ruby (Siemens)

the roentgenogram e g its analysis with subtraction photographic (VIGNAUD PASQUIER et coll 1963) or electronic techniques (EDHOLM & QUIDING 1970) were discussed in an earlier paper (HEMMINGSSON et coll 1972)

Material The cervical phantom previously described (HEMMINGSSON 1971) stood in as a substitute for a neck and was constructed of a cervical spine embedded in the soft tissue equivalent phantom material Mix D (Fig 1) Cylindrical rods or pellets of Mix D were introduced into the 25 mm bore hole that simulated the laryngeal cavity in the phantom these were placed on the cellular plastic material Frigolit, whose attenuation of roentgen radiation is negligible in comparison with Mix D in order to get these to lie anteriorly or in the centre of the drilled hole

Table 2

Visibility of rods and pellets in laryngeal cavity of phantom at ordinary radiography

Object in the laryngeal cavity	Rods without contrast medium				Pellets without contrast medium							
Diameter in mm	2	3	4	5	2	2	3	3	4	4	6	6
Film	K	K	K	K	K	M	K	M	K	M	K	M
~ 50 kV	—	—	—	—	—	—	—	—	—	—	—	—
~ 75 kV	—	—	—	—	—	—	—	—	—	—	+	+
~100 kV	—	+	+	+	—	—	—	—	—	—	+	+
~150 kV	—	+	+	+	—	—	—	—	—	—	+	+
~150 kV + 1 mm brass	—	++	+	++	—	—	—	—	—	—	++(+)	++(+)
~200 kV + 2 mm brass	+	++	+	++	—	—	—	+	+	—	++(+)	++(+)
1.17–1.33 MeV	+	++	+(+)	++								

— object not visible
\+ parts of object barely visible
++ whole object barely visible

The technical conditions in the phantom investigations are presented in Table 1. The tomograph was an MT 2 (Philips), automatic development processing suitable for the different types of films was employed.

Method. The average gradient in the density range 0.25 to 2.0 was determined for Kodak RP X-Omat film exposed between Ruby screens (Siemens). An aluminium step was used at tube potentials of 50, 60, 75 and 100 kV and at 150 and 200 kV a brass step was used, brass filters of 1 and 2 mm were added at 150 and 200 kV, respectively. Kodak RP X-Omat film was replaced in radiography with ^{60}Co by 3 M Sigma film. The examination by ordinary radiography was also performed with the experimental blue roentgen film Medichrome$_{B}$ (Agfa-Gevaert) (Table 1).

Ordinary radiography without contrast medium. Cylindrical rods and pellets of Mix D, 2 to 5 and 2 to 10 mm in diameter, respectively, were placed in the hole drilled to simulate the laryngeal cavity in the phantom for the investigation of the influence of the potential on the visibility of the laryngeal cavity and of objects of varying size within this cavity (Table 2). Exposures at different potentials were made with an a.p. beam direction and with a constant anode current of 100 mA, while the exposure time was varied in order to obtain the same film density at different potentials. The exposure time in examinations with ^{60}Co was 90 s and the beam direction was anteroposterior.

Table 2 *(cont.)*

Pellets without contrast medium				Pellets with contrast medium			Pellets with contrast medium on these and on the laryngeal wall		
8 K	8 M	10 K	10 M	2 K	3 K	4 K	2 K	3 K	4 K
–	–	–	–	+++	+++	+++	+++	+++	+++
–	+	+	+	+++	+++	+++	+++	+++	+++
+	+	+	+	+++	+++	+++	+++	+++	+++
+	+	++	++	+++	+++	+++	+++	+++	+++
++	++	++(+)	++(+)	+++	+++	+++	+++	+++	+++
++	++	++(+)	++(+)	++(+)	+++	+++	++(+)	+++	+++

+++ whole object clearly visible
K Kodak RP X Omat
M Medichrome

Ordinary radiography with contrast medium. A thin layer of Dionosil suspension (Glaxo) 0.5 mg/ml (manufacturer's number 9 I—1382) was applied to the pellets of Mix D with diameters of 2, 3 and 4 mm to determine the smallest visible soft tissue structure coated with contrast medium in the laryngeal cavity at different tube potentials; they were then placed in the centre of the laryngeal cavity of the phantom. The experimental conditions in ordinary radiography with contrast medium on the pellets were the same as in the examination without contrast medium (Table 2). The thickness of the contrast layer on the different pellets was determined by measurements with a magnifying glass with an inbuilt scale in roentgenograms of the pellets and found to be 0.5 ± 0.1 mm. Densitometry of roentgenograms of the pellets without and with contrast medium exposed with a tube potential of 75 kV was also performed so as to check that the contrast layer on the different pellets was of constant thickness. No significant difference in the relationships between the radiation absorption as recorded in the film obtained for the pellets without and with contrast medium was found at the 95 % confidence level.

The pellets with contrast medium were examined under the same conditions as described to determine whether the application of contrast medium to the walls of a laryngeal cavity influences the evaluation of the contained objects. The examination was performed with contrast medium on the inner surface of a 0.1 mm sheet of plastic foil against the walls of the laryngeal cavity of the phantom (Table 2).

EXPOSURE ANGLE 20°

Transverse section of the laryngeal cavity										
Operator direction	L	L	L	L	L	L	L	T	L	L
Beam direction ↓a p ↑p	↓	↑	↓	↑	↓	↑	↓	↓	↓	↓
Film system	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
~ 50 kV	+	+(+)	++	++	++	++	++	+(+)	+++	+++
~ 65 kV										
~ 75 kV	+(+)	+(+)	++	++	++	++	++	+	+++	+++
~ 100 kV	+(+)	+(+)	++	++	++	++(+)	++	+	+++	+++
~ 140 kV										
~ 150 kV	+( )	+(+)	++	++	++	++(+)	++	+	+++	+++
~ 150 kV + 1 mm b	+	++	++	++(+)	++	++	++	+	+++	+++
200 kV 2 mm b	++	+	++	++	++	++	++	+	++( )	++(+)

a

Fig 2 Visibility of pellets 2 3 and 4 mm diameters in laryngeal cavity of phantom at tomography at exposure angles of 20 (a) and 44 (b) Transverse section of the laryngeal cavity of the phantom ◯ pellet without contrast medium in the laryngeal cavity ● pellet with contrast medium in the laryngeal cavity ◯ pellet in the laryngeal cavity with contrast medium on both the pellet and the laryngeal wall L — tomography longitudinal to the phantom T — tomography transverse to the phantom S_1 — multisection cassette S — single film system One or two pellets barely visible (+) all pellets barely visible (+ +) all pellets clearly visible (+ + +)

Tomography without contrast medium The influence of tube potential on the visibility of objects in the laryngeal cavity in tomography and the importance of the position of the object in relation to the vertebral column were investigated at linear exposure angles of 20° and 44° Pellets of Mix D, 2, 3 and 4 mm in diameter without contrast medium, were placed posteriorly, centrally and anteriorly in the laryngeal cavity (Fig 2) Their distances from the anterior surface of the vertebral column were approximately 1 5, 2 5 and 3 5 cm respectively, corresponding with the position of the larynx in relation to the vertebral column The position of the objective plane (the pellets) was adapted to the middle pair of screens in a multisection cassette by exposures at intervals of 2 mm so that a film between this pair of screens was exposed at different potentials The exposure time was 0 4 s at an exposure angle of 20° and 1 s at 44°, while the anode current was varied from 10 mA to 200 mA to retain the same film density at the various potentials, the other experimental conditions appear in Fig 2

EXPOSURE ANGLE 44

Tra on f f yng f y	○	○		○	○		●	●
Ope d io	L	L	L	L	L	T	L	L
B m d ↓ p ↓ p	↓	↓	↓	↓	↓	↓	↓	↓
F lm y m	S_1	S_1	S_2	S_1	S_1	S_1	S_1	S_1
50 kV	+(+)	++			+	( )		+ +
65 kV		++	++					
– 75 kV	+(+)							+
– 100 kV	++	++( )	( )	( )	++	+	+	+
140 kV		( )	( )					
– 150 kV	++	( )		++( )				++
– 150 kV 1 mm br	++	++( )		( )	+	( )	++	+
200 kV 2 mm b	++	++	++	++		( )	++( )	( )

b

Fig 2 (For legend see opposite page)

The importance of the *tomographic direction in* combination with different potentials and exposure angles was also investigated The same pellets were placed laterally in the laryngeal cavity and tomography with exposure angles of 20° and 44 was performed in the longitudinal *direction* of *and* at *right* angles to the phantom at different potentials (Fig 2)

A *compari on* was also made between tomography with simultaneous and sequential exposures at an exposure angle of 44° and with potentials of *about* 65 100 and 140 kV without filtration and of 200 kV in combination with a 2 mm brass filter (Fig 2) The 2 3 *and* 4 *mm pellets* were placed in the centre of the laryngeal cavity and sequential exposures of an ordinary cassette with Ruby *screens* (Siemens) made at intervals of 2 mm The upper film in the multisection cassette which contained 7 films at 0 5 *cm distances* was then exposed at the level where the pellets were best defined Exposures were then made with the *object stationary* the different films being adapted successively to the objective plane by alteration of the tube axis.

Tomography with contrast medium Tomography with linear exposure *angles* of 20 and 44 was performed in the longitudinal axis of the phantom with contrast medium on 2 3 and 4 mm pellets These were *placed* centrally in the laryngeal cavity with the experimental conditions the same as previously Tomo-

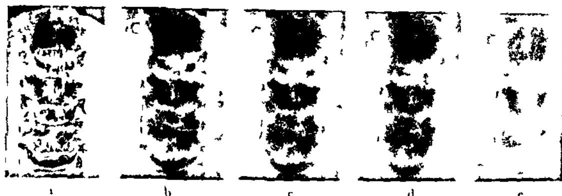


Fig 3 Ordinary radiography at 48 kV (a) 100 kV (b) 150 kV (c) 150 kV + 1 mm brass (d) 200 kV + 2 mm brass (e) Pellets of 6 8 and 10 mm diameters without contrast medium in laryngeal cavity of phantom

graphy was also performed with intervals of 0 5 cm at distances of 0 5, 1 0 and 1 5 cm from the centres of the pellets at 48 kV and 150 kV with an additional 1 mm brass filter in order to determine the influence of the potential on the blur from the contrast pellets outside the objective plane The contrast pellets in the centre of the laryngeal cavity were also examined with the addition of contrast medium applied to the plastic foil lying against the walls of the cavity (Fig 2)

Results

The average gradient for the Kodak RP X Omat film between Ruby screens was 2 2 ± 0 1 within the density range 0 25 to 2 0 with a potential of 50 to 200 kV

Ordinary radiography without contrast medium The visibility of the laryngeal cavity of the phantom and of the pellets (Fig 3) and rods in the cavity was successively improved with increasing tube potential up to 200 kV + 2 mm brass filtration (Table 2) No difference in visibility was obtained on the other hand, between potentials of 100 kV and 1 17 to 1 33 MeV ^{60}Co The pellets (Fig 3) and rods in the laryngeal cavity were not visible at all below 75 kV and appeared more clearly with increasing potentials up to 150 to 200 kV and brass filtration (Table 2) The 3 mm rod was clearly seen above 200 kV, as also were the pellets with diameters of (4—) 6 mm and over (Fig 3 c d, e) The possibility of demonstrating the object above 150 kV was better with than without, extra filtration (Fig 3 c, d) No difference in the visibility of the pellet was obtained with Kodak RP X Omat and Medichrome$_{\text{B}}$ films (Table 2)

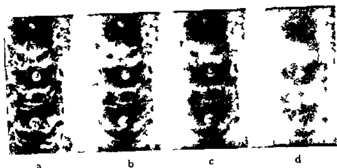


Fig 4 Ordinary radiography at 50 kV (a) 96 kV (b) 150 kV (c) and 184 kV + 2 mm brass (d) Pellets of 2 3 and 4 mm diameters coated with contrast medium in laryngeal cavity of phantom

Ordinary radiography with contrast medium The contrast pellet were well visible down to a diameter of 2 mm at all potentials (Table 2 and Fig 4), the radiographic contrast varied inversely with potential A layer of contrast medium applied to the inside of the wall of the laryngeal cavity failed to effect any change (Table 2)

Tomography without contrast medium The results of tomography of the 2 3 and 4 mm pellets appear in Figs 2 5 and 6 Only minor changes in the visibility of the walls of the laryngeal cavity and of the contained pellets took place under different experimental conditions

It was difficult to define the contours of the pellets when they were situated posteriorly in the laryngeal cavity at potentials below about 100 kV and at exposure angles of 44 or 20 (Fig 5 a b d e) This was due to the fact that they were partly obscured by linear blur from the cervical vertebrae this diminished with increasing potential when the visibility progressively improved Fig 5 c f) The pellets were defined at 200 kV somewhat more clearly with a single film and Cronex high definition screens than with a multisection cassette possibly due to the fact that with the former the radiographic mottle was possibly reduced (Fig 5 c f) Linear blur was rather less evident when the exposure angle was increased from 20 to 44° (Fig 5 a—f) It was also slightly less marked when the direction of the beam was changed from a p to p a i e the distance from the cervical vertebrae to the film plane was increased

Tomography in the longitudinal axis of the phantom provided better possibilities of demonstrating the pellets than when the direction was perpendicular to the longitudinal axis (Figs 2 6) The linear blur in the roentgenogram which rendered evaluation difficult in tomography at right angles to the longitudinal axis corresponded to the vertebral end plates in the cervical spine This was

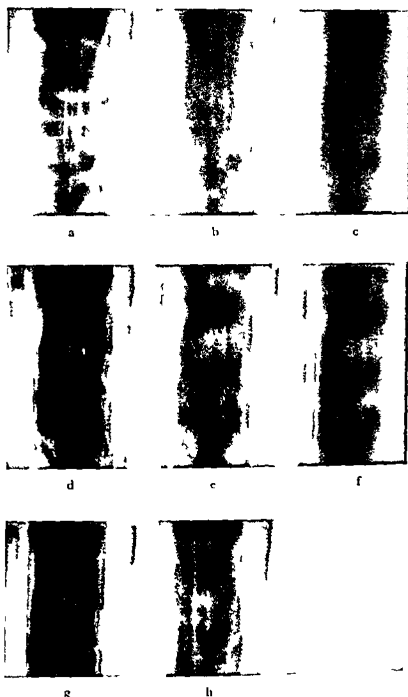


Fig. 5. Tomography at 48 kV (a), 98 kV (b) and 150 kV + 1 mm brass (c) at an exposure angle of 14° and at 48 kV (d), 98 kV (e), 200 kV + 2 mm brass (f), 52 kV (g) and 48 kV (h) at an exposure angle of 20°. Pellets of 2, 3 and 4 mm diameters located in the posterior (a—f), central (g) and anterior (h) parts of the laryngeal cavity of phantom. A multisection cassette was used in all cases except (f) where sequential exposure with Cronex intensifying screens was used. A p beam direction.

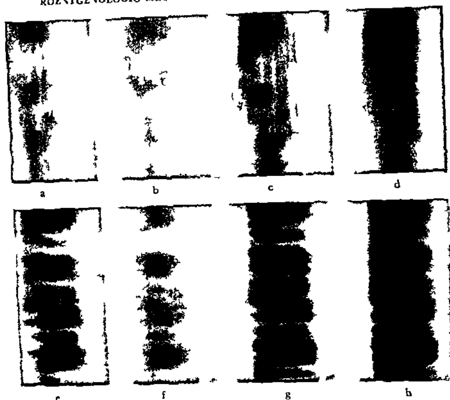


Fig 6 Tomography longitudinal (a—d) and transverse (e—h) to the phantom at 76 kV (a) 156 kV + 1 mm brass (b) 48 kV (c) 106 kV (d) 76 kV (e) 158 kV + 1 mm brass (f) 48 kV (g) and 102 kV (h) exposure angles of 20 (a, b e f) and 44 (c d g h) Pellets of 2 3 and 4 mm diameters without contrast medium lie to the left in laryngeal cavity of phantom

reduced by increasing the potential although it complicated evaluation of the pellets even at high potentials

Comparison between tomography with a multisection cassette and sequential exposure of a cassette with Ruby screens at 65 100 140 and 200 kV disclosed no difference in the demonstration of pellets with diameters of 2, 3 and 4 mm (Fig 2) The 3 mm pellet with sequential exposures had relatively *sharp out* lines at a depth of 6 mm at 100 kV

Tomography with contrast medium Contrast pellets down to 2 mm diameter were well visible with tomography at exposure angles of both 20° and 44° (Figs 2 7 c h) although here again with progressively less contrast with increasing potential No difference in the visibility of the pellets with and without contrast medium against the wall of the laryngeal cavity was evident

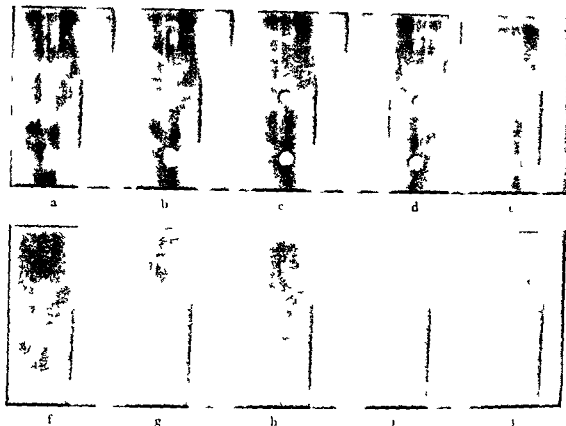


Fig. 7. Tomography at an exposure angle of 44°. 8.5 cm (a, f), 9.0 cm (b, g), 9.5 cm (c, h), 10.0 cm (d, i) and 10.5 cm (e, j) above the table top. Tube potentials of 48 kV (a—e) and 150 kV + 1 mm brass (f—j). Pellets of 2, 3 and 4 mm diameters coated with contrast medium lie in the central part of laryngeal cavity of phantom.

The linear blur from the contrast covered pellets was considerable even 1 cm from the objective plane at 48 kV (Fig. 7a, e). This was reduced by increasing the tube potential to 150 kV and adding a 1 mm brass filter (Fig. 7f–j).

Discussion

Ordinary radiography without contrast medium. The wall of the laryngeal cavity as well as the rods and pellets inside the cavity may here be best evaluated at 150 to 200 kV with an additional brass filter (Table 2, Fig. 3). This is in agreement with theoretic calculations that an air filled cavity in a cervical model as well as contained objects would be best visible at and above 150 keV (HEMMINGSSON & LUNDQVIST 1972). Little change in the radiographic contrast occurs above this level which explains why no difference in visibility is evident between examinations with ^{60}Co and 150 to 200 kV with filtration. The roentgenogram has approximately the same contour sharpness on examination

with ^{60}Co as in ordinary radiography, despite the large focal spot of 2 cm × 2 cm in ^{60}Co examinations This was pointed out by McDONNEL et coll (1958) who reported no appreciable difference in harpne s in comparing focal spots of 1 2 cm and 0 5 mm in radiography with ^{60}Co

Good agreement in the size of the mallest visible oft tissue structure in the laryngeal cavity was apparent in comparing the phantom investigations with ordinary radiography and the theoretic calculations The latter suggested that the contour of a oft tissue structure about 2 mm thick hould be visible in the larynx at 100 to 200 keV at a bone disturbance of 1 mm while it has to be about 5 mm thick to be evident at 30 keV The corre ponding measurements in the phantom experiments are about 3 mm for a rod and 6 mm for a pellet at 150 to 200 kV with a brass filter, and more than 5 mm for a rod and even more than 10 mm for a pellet at a potential of about 50 kV The above potentials have a mean photon energy corre ponding to about 100 keV and 20 to 30 keV respec tively That the size of the mallest vi ible oft tissue structure in the phantom in vestigations was somewhat greater than in the calculations is to be expected ince the latter were performed for a rectangular structure while the objects in the phantom investigations were cylindrical rods or pellets Furthermore the calcula tions were performed for monoenergetic radiation which could not be attained in the phantom investigation In addition no consideration was taken in the calcula tions of the different unsharpne s factors and the effect of scattered radiation

The size of the mallest visible object in the laryngeal cavity of 3 to 6 mm is al o in agreement with the results obtained by TUDDENHAM et coll (1954) who stated that a 5 mm object of plexiglas (methylmethacrylate) was vi ible in the region of the thoracic spine at 2 000 kV while such an object had to be more than twice as large to be evident at 80 kV no investigation between the e poten tials was made That the pellets must have a diameter greater than that of the rods in order to be visible may probably be explained by the fact that it is ea ier to perceive and fill in the traight contour of a rod within the areas where it cannot be defined clearly Similar results have been obtained by NEWELL & GARNEAU (1951) in investigations of different haped objects

Ordinary radiography with contrast medium Contrast pellets are here visible down to a diameter of 2 mm at all potentials both with and without the applica tion of contrast medium to the wall of the laryngeal cavity (Table 2 Fig 4) The attenuation in the iodine-containing contrast medium decreases with in creasing potential o that it is difficult to outline the entire contours of the pel lets at 200 kV and 2 mm bra s filtration The risk of ob curing a mall change by a thick layer of contrast medium must al o be taken into consideration A potential of about 150 kV with for example 1 mm of bra s, reduces this risk considerably and hould probably always be used

Tomography without contrast medium. The tomographic investigations were performed only with linear movements because of the desirability of a short exposure time, preferably below 0.5 s, in roentgenologic examinations of the larynx. The shortest exposure times with exposure angles of 20° and 44° are 0.4 s and 1.0 s respectively for the linear tomographic equipment M1 2 (Philips) available, while a circular or elliptical movement requires a minimal exposure time of 2.8 s with the Polytome (Philips) tomograph.

The visibility of the laryngeal cavity *in the phantom in tomography* is affected mainly by linear blur from the skeletal structures of the cervical spine. When the direction of the beam is changed from a.p. to p.a., this blur becomes rather less prominent owing to the consequent increase in the distance between the cervical spine and the film plane (Fig. 2). For practical reasons a p.a. beam direction cannot be used however with the equipment available at present for frontal tomography since this would mean that the patient would have to lie prone.

Reduction of the linear blur is also obtained by increasing the exposure angle from 20° to 44° (Figs 2, 5 a—f). The greatest effect on blur is however obtained by increasing the potential so that its radiographic contrast is diminished and the object in the laryngeal cavity may more easily be evaluated (Figs 2, 5). This is in agreement with the findings of WHITNER (1956) and VOURINEN (1959) that the 'section thickness' decreases with reduced radiographic contrast. It may further be assumed that the sharpness of the interfering linear blur from the skeleton may be reduced with the decrease in radiographic contrast obtained by raising the potential (EDHOLM 1960). The best possibility of evaluating the larynx in its entire sagittal plane with frontal tomography at linear exposure angles of 20° to 44° and an a.p. beam direction therefore lies in a potential of about 150 kV with 1 mm brass filtration.

A tomographic direction transverse to the phantom produces greater interference with the linear blur from the cervical spine than one oriented longitudinal to the phantom, thereby diminishing the possibility of evaluating the laryngeal cavity of the phantom and objects lying close to its walls (Figs 2, 6). In spite of the fact that the phantom has no lower jaw, it may be assumed that a frontal tomographic direction in the longitudinal axis of the neck is to be preferred.

A multisection cassette, which in examination of soft tissue structures surrounded by air gives results equal to those obtained by sequential exposure (Fig. 2), should be used so as to obtain tomograms at different levels in the same respiratory and phonation phase. A distance of 0.5 cm between adjacent films in the multisection cassette is suitable in view of the large 'section thickness' illustrated by the fact that the 3 mm pellet without contrast is outlined relatively sharply to a depth of 6 mm at an exposure angle of 44°. The intensifying screens in the multisection cassettes available at present are adapted for a po-

tential of about 70 to 100 kV and therefore other screen combinations are needed for simultaneous tomography at 150 to 200 kV.

Constant anode current could not be used in the tomographic investigations because of the fixed exposure time. This means that because of the high anode current the size of the focal spot may be somewhat greater at the lower potentials (MATTSSON 1963) with consequently greater geometric unsharpness. A small increase in the size of the focal spot at the lower potentials may be considered to be of little importance in the present comparison since this affects the visibility of both the object examined in the laryngeal cavity and the interfering skeletal structures in the tomogram.

Tomography with contrast medium. The contrast pellets are demonstrated better than those without contrast medium down to a diameter of 2 mm, at all potentials (Figs. 2–7). It is difficult to outline the 2 mm pellet at a potential of 200 kV with a 2 mm brass filter as in ordinary radiography with a contrast medium. The disadvantage of the considerable linear blur from the contrast pellets outside the objective plane at low potentials is reduced considerably when the energy is increased, however (Fig. 7); this is due to the fact that the section thickness diminishes with reduced radiographic contrast (WILLNER 1956, VLORINEN 1959). A potential of about 150 kV combined with a filter say of 1 mm brass should therefore be used if contrast examination of the larynx is performed with linear tomography.

Filtration of the beam and dose to the patient. A potential of about 220 kV combined with extra filtration of 1.32 mm Al, 2.07 mm Cu, 1.10 mm Cd and 0.50 mm Pb are required to obtain an energy spectrum with a maximum at 150 to 200 keV. The maximum will then lie at about 161 keV, while it will be situated at about 60 keV at the same potential if only the inherent filtration of the tube of 4 mm Al is used (HETTINGER & STARFELT 1958). The extra filtration of 1 to 2 mm brass consisting of about two-thirds Cu and one third Zn in the present phantom investigations may be assumed to exert rather a smaller effect on the energy distribution in the spectrum, i.e. its maximum should lie slightly below 150 keV at a potential of 200 kV and 2 mm brass filtration.

Brass has been chosen as the filter material at 150 to 200 kV as it possesses practically the same filtering properties as copper (BEIQUE & ROTENBERG 1965) but is more durable and easier to handle. It reduces the amount of low energy radiation considerably more than that of high energy and has somewhat better filtering properties than iron in this respect (MAGUIRE et coll. 1965). It produces somewhat more scattered radiation than the latter, however (LINDELL 1954, WALSTAM 1954).

The dose to the skin and gonads is lowered with increased potential and filtration with, for example, 1 mm brass. ETTER et coll. (1959) reported that the

skin and gonadal doses were reduced by 60 to 80 per cent by filtration with 3.0 mm Al + 0.375 mm Cu at 95 kV compared with examinations at 64 kV and 2 mm Al. Filtration with more than 0.3 to 0.4 mm Cu produces very little reduction in the dose to the skin and gonads at potentials between 50 and 150 kV (BEIQUE & ROTENBERG 1965). A further increase in the filtration and the potential to 200 to 300 kV lead to no increase in the dose to the body. This is because the higher energy of the photons is compensated by the decrease in the number of photons absorbed and the sensitivity of the film-screen system to photon radiation is not changed (ATTIX & ROESCH 1968).

Radiographic examinations with photon energies of about 1 to 2 MeV, with e.g. ^{60}Co, increase however the dose to the body considerably on account of the slow film-screen system with high gradation that is usually used to compensate for the low radiographic contrast otherwise obtained. An examination with 2 000 kV and industrial film between lead screens thus produces a skin dose at least twenty times higher than with 80 kV and a conventional film-screen system in pulmonary radiography (TUDDENHAM et coll. 1954). Since radiography with filters of relatively heavy metals, such as iron, copper or brass, at a potential of about 200 kV affords about the same information as at 1 to 2 MeV, the latter method should be avoided in conventional diagnostic radiographic examinations.

Conclusion

Objects in the laryngeal cavity of the phantom are demonstrated best in the frontal projection when they are coated with a thin layer of contrast medium, both in ordinary radiography and tomography. A pellet with a diameter over 2 mm may be evaluated under these conditions at all potentials between 50 and 150 kV and 1 mm brass filtration. A contrast medium may therefore be used in roentgenologic examination of the larynx with a potential of about 150 kV and a 1 mm brass filter both in ordinary radiography and tomography in order to reduce the risk that a minor lesion behind the layer of contrast medium may be obscured. The dose to the patient with this potential and filtration is lower than with the conventional lower potentials.

Contraindications for examination with contrast media will suggest tomography with a multisection cassette in the longitudinal direction of the neck or ordinary radiography without contrast medium but with a high potential. A potential of about 150 kV with filtration should be used for optimal evaluation of the larynx in its entire sagittal plane in linear tomography at 20 to 44°, 150 to 200 kV with filtration is to be preferred in ordinary radiography without contrast medium. Without movement unsharpness which occurs in tomographic

examinations of laryngeal lesions structures with a diameter of 2 to 3 mm and 4 to 6 mm should then be visible in frontal tomography and ordinary radiography respectively. This is due to the fact that the roentgen contrast of the linear blur from the cervical spine is reduced in the objective plane of tomography. A similar but less marked, effect on linear blur is obtained by increasing the exposure angle from 20° to 44° and by changing the direction of the beam from a.p. to p.a.

The optimal potential in ordinary radiography of the larynx without contrast medium, i.e. 150 to 200 kV with filtration agrees with the theoretic calculation that the optimal photon energy for the frontal demonstration of the laryngeal cavity is 150 to 200 keV.

SUMMARY

Ordinary radiography and tomography with and without contrast medium of the larynx were investigated with a cervical phantom constructed of a human cervical vertebral column. The methods were compared at potentials varying from 50 kV to 200 kV as well as with 1.17 to 1.33 MeV ^{60}Co. A comparison between simultaneous and sequential exposures in tomography is also presented.

ZUSAMMENFASSUNG

Konventionelle Radiographie und Tomographie mit und ohne Kontrast-Mittel des Larynx wurden an einem Halsphantom, das mit Hilfe einer menschlichen Wirbelsaule hergestellt war, untersucht. Die Methoden wurden bei Spannungen zwischen 50 kV und 200 kV sowie zwischen 1.17 und 1.33 MeV ^{60}Co verglichen. Es werden weiterhin gleichzeitige mit aufeinander folgenden Exponierungen bei der Tomographie verglichen.

RÉSUMÉ

L'auteur a fait un travail de recherche sur la radiographie simple et la tomographie du larynx avec et sans moyen de contraste en utilisant un fantome de cou fait avec une colonne vertebrale cervicale humaine. Il a compare ces methodes avec des tensions allant de 50 kV à 200 kV et aussi avec le rayonnement de 1.17 a 1.33 MeV ^{60}Co. Il presente aussi une comparaison entre les films de tomographie simultanee et les films tomographiques exposes separement les uns apres les autres.

REFERENCES

ARDRAN G. M. and EMRYS-ROBERTS E.: Tomography of the larynx. Clin. Radiol. 16 (1965), 369.

ATTIX F. H. and ROESCH W. C.: Radiation dosimetry. Second edition. Vol. 2. Academic Press, New York, London 1958.

BEIQUE R. A. and ROTENBERG A. D.: Effect of filtration in diagnostic radiology. J. Canad. Ass. Radiol. 16 (1965), 59.

BRAUER W Die Methodik der Larynx Kontrast Schichtuntersuchung Fortschr Röntgen 82 (1955), 521
EDHOLM P The tomogram Its formation and content Acta radiol (1960) Suppl No
— and QUIDING L Elimination of blur in linear tomography Acta radiol Diagnosis (1970), 141
FITER L L KAMMER A C, DATTOLI J A et coll Radiation reduction by combined copper and aluminium filtration in radiography Radiology 77 (1959) 863
HEMMINGSSON A Cervical phantom for evaluation of different methods of roentgen examination of the larynx Acta radiol Diagnosis 11 (1971), 515
— and LUNDQVIST H Optimum photon energy in ordinary radiography of the larynx Acta radiol Diagnosis 12 (1972) 305
— JUNG B and LUNDQVIST H Soft tissue intensification in frontal roentgenography of the larynx Acta radiol Diagnosis 12 (1972) 593
HETTINGER G and STARFELT N Bremsstrahlung spectra from roentgen tubes Acta radiol (1958) 381
JACKSON C The bronchial tree its study by the insufflation of opaque substances in living Amer J Roentgenol 5 (1918) 112
LANDMAN G H M Laryngography and cinelaryngography Excerpta Medica Foundation Amsterdam 1970
LEBORGNE F Cancer laríngeo y tomografía (In Spanish) J Garcia Morales Montevideo 1938 Cited by Landman (1970)
LINDELL B Secondary roentgen radiation Acta radiol 41 (1954) 353
MACGUIRE G H The larynx Simplified radiological examination using heavy filtration and high voltage Radiology 87 (1966) 102
— BEIQUE R A and ROTENBERG A D Selective filtration The practical approach to high kilovoltage radiography Radiology 85 (1965) 343
MATTSSON O Focal spot variations with exposure data — important factors in daily routine Acta radiol Diagnosis 7 (1968) 161
MCDONNELL C M BERMAN H I and LODMELL L A Supervoltage roentgenography Amer J Roentgenol 79 (1958) 306
NEWELL R R and GARNEAU R The threshold visibility of pulmonary shadows Radiology (1951) 109
POWERS W E MCGEE H H and SEAMAN W B Contrast examination of the larynx and pharynx Radiology 68 (1957) 169
STEPHANI J De l'emploi de l'antidiffuseur pour les radiographies pulmonaires J Radiol Electrol 13 (1929) 393
THORNBURY J R and LATOURETTE H B A comparison study of laryngography techniques Amer J Roentgenol 99 (1967) 555
TUDDENHAM W J GIBBONS J I HALE J and PENDERGRASS L P Supervoltage and multiple simultaneous roentgenography New technics for roentgen examination of the chest Radiology 63 (1954) 184
WALSTAM R Dose measurements on secondary roentgen radiation Acta radiol 41 (1954) 348
VIGNAUD PASQUIER J DANIC J et SUDAKA J La méthode de soustraction Application à la radiographie en O R L Rev Laryng (Bordeaux) (1963) Suppl No 865
WILLNER O On the thickness of the layer in rectilinear tomography Acta radiol 46 (1956) 512
VUORINEN P Image contrast A factor to be considered in the determination of layer thickness in tomography Acta radiol 51 (1959) 305

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ANGIOGRAPHY IN MYOMAS OF THE GASTROINTESTINAL TRACT

by

J KALDE, CH SILSETH and U TYLEN

Tumours arising from the muscular layer of the wall of the gastrointestinal tract may be benign (leiomyomas) or malignant (leiomyosarcomas), single or multiple and sometimes producing symptoms only of bleeding Problems often arise in differentiating the two forms as the clinical signs may be similar these are further accentuated by difficulties in the histologic typing Radiographic findings in 24 mesenchymal tumours have therefore been examined to determine whether preoperative radiographic diagnosis and differentiation between benign and malignant conditions are possible Special attention was paid to the angiographic examinations since selective visceral angiography alone appeared able to provide the diagnosis

Material and Methods Twenty-one cases of leiomyoma or leiomyosarcoma of the gastrointestinal tract were examined angiographically during a period of 8 years (1963—1971) Three neurinomas were also included because of their mesenchymal origin and radiographic similarity to myomas. The material included 10 males and 14 females aged from 32 to 83 Twenty three cases were

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Fig. 1. Benign leiomyoma. a) Barium meal examination of esophagus and stomach. Large mass in the herniated part of the fornix with central ulceration. The diagnosis of tumour was not made at this primary examination. b) Selective angiography of the left gastric artery. Highly vascularized tumour in the herniated part of the fornix.

examined both with barium and by selective visceral angiography; angiography was performed alone in 1 case. The femoral artery was punctured percutaneously and depending on the site of the tumour the celiac, left gastric, superior or inferior mesenteric arteries were catheterized. Thirty to forty ml (gastric and inferior mesenteric arteries 15 to 20 ml) contrast medium were injected and serial radiography performed. All cases were operated upon and a histologic diagnosis was obtained, the slides in all but 2 cases being reviewed for this particular investigation. Nine of the tumours were classified as malignant and 9 as benign. Six growths were highly cellular with evidence of some mitoses; the histologic appearances were, however, such as to warrant the label only of 'potentially malignant'.

Results

Gastric tumours. Ten tumours (9 myomas and 1 neurinoma) arose from the stomach. Three were classified as benign, 4 malignant and 3 as belonging to the third group of highly cellular tumours. The most frequent *clinical* sign in



Fig 2 Leiomyoma highly cellular a) Barium meal examination of the stomach Lateral displacement of the stomach by a large partially calcified tumour Only slight involvement of the gastric wall and none of the mucosa b) Selective angiography of the left gastric artery Highly vascularized growth with numerous large neoplastic vessels No early filling of veins



Fig 3 Le[illegible]sa[illegible]ma [illegible]) Barium meal examination of the esophagus and stomach Anterior displacement of the stomach Small calcifications in the retrogastric tumour (→) b) Selective [illegible] angiography performed for acute gastrointestinal bleeding Large tumour containing numerous neoplastic vessels arising from branches of the left gastric artery Extravasation of contrast medium (→)



Fig. 4. Benign neurinoma. Selective celiac angiography, lateral projection. Highly vascularized and well circumscribed growth at the fornix supplied by short gastric arteries. (Electronically subtracted 70 mm fluorograms reproduced from television monitor with a polaroid camera.)

6 cases was hemorrhage, an upper abdominal mass was palpated in 4 of these and abdominal pain was present as well in 2 cases. Seven growths were situated in the corpus and 3 in the cardia and fornix, one of these lying in the herniated part of the stomach above the diaphragm (Fig. 1).

All 4 leiomyosarcomas and one highly cellular myoma extended mainly extraluminally and caused compression or displacement of the stomach and eventually the colon (Figs 2, 3). Two of these extragastric neoplasms were partly calcified.

All the gastric myomas were demonstrated by a barium meal although, the growth in the herniated fornix (Fig. 1) was recognized only in retrospect and 3 extragastric tumours with only minimal mucosal involvement at first suggested a hepatic or retroperitoneal origin (Figs 2, 3). Angiography demonstrated that the latter were smooth, well circumscribed and richly vascularized by small capillary vessels with diffuse accumulation of contrast medium, the intraluminal tumours being best defined in an inflated stomach in the lateral projection (Fig. 4). Arteriovenous shunting was never present in the gastric leiomyomas. Encroachment upon or occlusion of vessels by benign tumours was not encountered. Two of the potentially malignant growths were richly vascularized, contained neoplastic vessels, and were drained by large veins (Fig. 2), another was only sparsely vascularized. Arteriovenous shunting with early filling of veins was never evident.



Fig 5 Benign leiomyoma Selective celiac angiography (tip of the catheter at orifice of the left gastric artery) Relatively highly vascularized and well circumscribed growth at the fornix

All 4 gastric leiomyosarcomas were supplied by branches of the gastric arteries and were clearly demonstrated as being of gastric origin at angiography *even if* they extended extraluminally (Fig 3) In one of these cases in which angiography was performed because of acute bleeding its site in *the tumour* was demonstrated (Fig 3 b) Gastric leiomyosarcomas were large 10 to 25 cm in diameter well vascularized and supplied by large arteries *The* malignant tumours contained numerous neoplastic vessels arteriovenous shunts with early filling of the gastric splenic or portal veins were present in 2 instances One leiomyosarcoma involved gastric arteries *but* in none was venous occlusion evident Hepatic metastases were present in one of the gastric leiomyosarcomas

Tumours of the small intestine Intestinal bleeding *occurred* in 11 out of 13 cases of myoma of the small intestine a palpable abdominal mass was the indication for radiographic examination in the other 2 *cases* One of the growths was situated in the third part of the duodenum and one at the duodeno-jejunal junction Nine were in various parts of the *jejunum* and ileum while 2 tumours arose from the wall of the terminal ileum

Six *growths* were classified histologically as benign leiomyomas and 5 as being malignant Two myomas were regarded as potentially malignant Multiple leiomyosarcomas were present throughout the *small* intestine in one case (Fig 6) Three of the leiomyosarcomas had hepatic (Fig 9 b) and 2 lymph node



Fig 6 a) Barium meal examination of the small intestine Multiple tumours of mainly extra luminal growth in the small intestine causing compression of intestinal lumen but no obstruction (→) Ulceration in one of the growths (>→) b) Selective angiography of superior mesenteric artery Highly vascularized tumours (leiomyosarcomas) no differentiation with benign leiomyomas possible (cf fig 8)

metastases The size of the benign neoplasms varied between 2 and 6 cm, while the malignant growths were between 2 and 25 cm in diameter

The diagnosis of a small intestine neoplasm was made in 9 out 12 cases by means of a barium meal the examination was repeated in 2 cases but failed to lead to the diagnosis, not even in retrospect, the last case was not so examined Typical appearances at these examinations caused by a growth was compression or displacement of the loops of the small intestine without complete obstruction of the lumen Ulceration of the tumour was evident in 2 cases (Figs 6 a 7 a)

All 13 tumours were demonstrated at angiography Six benign as well as 2 potentially malignant neoplasms were richly vascularized and in 6 of these against benign gastric and both duodenal growths, arteriovenous shunting with early filling of veins was present (Fig 8) Encroachment upon vessels was not evident

One of the leiomyosarcomas of the small intestine was partially calcified and 5 were growing mostly extraluminally and only producing slight compression of the intestinal lumen



Fig 7 Leiomyosarcoma a) Barium meal examination of the small intestine Tumour with large ulcer in the distal loops of ileum b) Selective angiography of superior mesenteric artery Enlarged branches supply the highly vascularized tumour in the ileum

Out of the 5 neoplasms classified as malignant rich vascularization with arteriovenous shunts was evident in only 2 the other 3 tumours being large and partially necrotic Neoplastic vasculature even if sparse was however present Fig 9 a) Vessel displacement by these large tumours was evident encroachment however only in one case

Colic tumours Only one myoma arose from the large intestine This was palpable and there was an episode of bleeding 6 years before the examination A barium enema revealed displacement of the sigmoid colon but no infiltration of the mucosa Selective angiography of the superior and inferior mesenteric arteries demonstrated a well vascularized tumour 25 cm × 17 cm in size mainly supplied by branches of the inferior mesenteric artery The mass was fed by wide arteries contained numerous neoplastic vessels but arteriovenous shunting was absent (Fig 10) because of its size and rich vascular supply it was inoperable Histologically it was classified as a potentially malignant leiomyoma although the subsequent history proved this conclusion to be doubtful the patient was alive and well more than 5 years after the first examination when repeat angiography failed to disclose any changes in the appearances



Fig. 8. Benign leiomyoma. Selective angiography of superior mesenteric artery. Small richly vascularized tumour in jejunum with marked and early filling of a draining vein (→).

Discussion

MORGAGNI (1762) was the first, according to NEUBER (1920), to describe a smooth muscle tumour of the stomach. VIRCHOW (cited by NEUBER 1920 and SCHRODER 1936) distinguished between the 'smaller inner' (submucosal) and 'larger outer' (subserosal) myomas. Masses of the latter group might reach a considerable size. This was confirmed in the present series with large leiomyomas or leiomyosarcomas displaying prominent extraluminal growth but causing no obstruction.

Some controversy exists in the reports on the incidence of leiomyomas of the gastrointestinal tract. SCHRODER (1936) and HANNO & MENSCH (1944) regarded gastric or jejunal leiomyomas as uncommon. GOLDEN & STOUT (1941) reported 23 incidental leiomyomas in a total of 5 869 autopsies and SHANDALOW (1955) only 3 myomas in 2 618 autopsies. RIVER et coll. (1956) in a comprehensive review of benign neoplasms of the small intestine found 179 myomas reported in the literature. MEISSNER (1944), however, described small gastric leiomyomas (up to 0.7 cm in diameter) in 16 per cent of a series of 50 routine autopsies and according to HUGEL (1969) small leiomyomas without clinical signs are frequent.

The main clinical signs of myomatous gastrointestinal tumours are said to be intermittent hemorrhage and obstruction (GOLDEN & STOUT 1941, RIVER et coll. 1956, LICHNER & CONOLLY 1959, REIHLERSCHEID 1959, MEYERS & KING

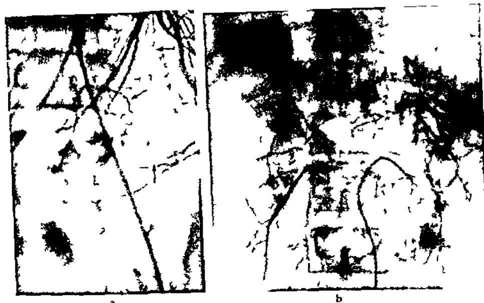


Fig 9 a) Large inoperable leiomyosarcoma of the small intestine Angiography Only a few small neoplastic vessels in the upper part of the tumour the size of which cannot be exactly defined b) Selective angiography of celiac axis two years later Multiple highly vascularized hepatic metastases

1968) Large palpable neoplasms may of course cause abdominal pain (WOLFE & TESLER 1958)

The 24 cases of the present material of mesenchymal (21 myomas and 3 of neural origin) growths of the gastrointestinal tract even if large failed to present clinical signs of intestinal obstruction doubtless due to their predominantly extra luminal growth Gastrointestinal hemorrhage often intermittent, was present in 18 cases Seven neoplasms could be palpated and abdominal pain or diffuse gastric discomfort was present in 2 cases

The radiographic diagnosis of gastrointestinal myomas is difficult with ordinary methods Calcifications may be evident in conventional abdominal films (SCHRODER and were found in 3 of the present series. Gastric myomas are usually diagnosed by barium meal examination (REUTER et coll) The intraluminal tumours in our series (all benign or highly cellular) were easily detected as smooth well defined masses. However a leiomyoma in the herniated part of the stomach was recognized only in retrospect. BOIJSEN et coll (1966) in angiography of gastric leiomyomas observed neoplastic vascularity and displacement of vessels as in malignant growths but a smooth outline was helpful in the differentiation



Fig. 10. Selective angiography of inferior mesenteric artery. Large tumour with numerous wide neoplastic vessels. No arteriovenous shunting evident.

REUTER et coll. reported from a material of angiographically examined gastric tumours that 2 out of 5 leiomyomas presented no abnormal appearances, while 3 had a moderate number of malignant vessels and involvement of the gastric arteries. None of the leiomyomas had early venous drainage.

Three intraluminal benign and one potentially malignant gastric tumour of the present material had displaced vessels and presented evidence of rich vascularization with a homogeneous accumulation of contrast medium in its tiny vessels, but no arteriovenous shunting or vessel encroachment (Figs. 1, 4, 5). The fifth (a gastric neurinoma, potentially malignant) was a large growth and less vascularized, probably due to necrosis. All gastric leiomyomas were smooth in outline.

All the 4 malignant and the one potentially malignant myoma were causing displacement of the stomach or intestines. When the mucosal involvement is only slight such growths may simulate those arising from the pancreas, liver or elsewhere in the tissues adjacent to the stomach (Figs. 2, 3). Angiography in these cases, however, will determine the origin of the neoplasm. All extraluminal myomas were supplied by branches of the gastric arteries. They contained numerous neoplastic vessels and in 2 very large leiomyosarcomas arteriovenous shunting with early filling of large draining veins was present.

Barium meal examinations, even if repeated, may fail to reveal a small intestine myoma (KLOI… & CRAWFORD 1935, GOLDEN & STOUT 1941, HANNO & MENSCH 1944, LECHNER & CONOLLY 1959, BOIJSEN & REUTER 1967). Three tumours of the present material remained undiagnosed by such an examination.

Angiographic findings in leiomyomas of the small intestine were first described by BOIJSEN & OLIN (1964) and further cases of benign or malignant myomas by

DEBRAY et coll (1965) BOIJSEN & REUTER (1966 1967), LYONE & BRYAN (1968) MEYERS & KING (1968) KLEIN et coll (1971), ETIENNE et coll (1971) MEYERS (1971) and OLSSON (1972) All the tumours of the small intestine of the present series were diagnosed by angiography although the criteria in gastric leiomyomas or leiomyosarcomas were different from those in intestinal growths Even small benign leiomyomas were characterized by the presence of numerous abnormal vessels and — in contradistinction to gastric leiomyomas — by arteriovenous shunts (Fig 8) The same occurred in smaller sarcomatous tumours Both duodenal leiomyomas however presented similar conditions to those demonstrated in gastric tumours i e rich vascularization but no proven arteriovenous shunting As in gastric tumours angiography determines the origin and permits the differential diagnosis against pancreatic carcinoma (OLSSON 1972) Three large malignant tumours of the small intestine were only sparsely vascularized and contained small neoplastic vessels arteriovenous shunting was absent These appearances were probably caused by extensive necrotic or cystic changes in the masses (Fig 9 a) Hepatic metastases, however were richly vascularized and had arteriovenous shunts (Fig 9 b)

A considerable risk of a sarcomatous change in a leiomyoma is said to exist (KLOPP & CRAWFORD) The histologic diagnosis however is difficult and according to GOLDEN & STOUT only small leiomyomas accidentally detected at autopsy or at operation can be regarded as entirely benign The differential diagnosis between benign and malignant forms probably depends more on the biologic behaviour than on histologic findings (KLOPP & CRAWFORD) Six tumours of the present series could not be classified either as benign or malignant Angiographically 2 of these highly cellular myomas were small bowel growths, richly vascularized with early filling of veins and could not be distinguished as benign or highly vascular and malignant Two tumours (one gastric and the only colic) were thought to be malignant as far as the angiographic findings were concerned (Figs 2 10) it was however, noteworthy that no arteriovenous shunting was present

Preoperative biopsy with a gastroscope was not possible in the case presented in Fig 2 a the tumour was entirely extraluminal and the gastric mucosa was intact which also explained the normal gastroscopy findings Metastases in the omentum at operation were considered to be present and total gastrectomy was performed Histologic examination revealed a highly cellular growth with no obvious evidence of malignancy and no metastases

The second case radiographically and histologically similar to the one of gastric tumour was proved to be of colic origin at angiography It has been stated that the large size apart from the histologic findings and biologic behaviour of a myoma of the gastrointestinal tract indicates malignancy (GOLDEN



Fig 10 Selective angiography of inferior mesenteric artery Large tumour with numerous wide neoplastic vessels No arteriovenous shunting evident

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& STOUT). This only myoma of the colon, supplied by the inferior mesenteric artery and richly vascularized by numerous neoplastic vessels, was approximately 25 cm in diameter. However, in spite of the vascularization and large draining veins no early filling of the veins occurred. The history of this case clearly eliminated malignancy. Cases in which leiomyomas of the gastrointestinal tract reach considerable size without being malignant may thus exist. A similar case of a large benign but necrotic leiomyoma of the colon, however, not examined by angiography before operation, has been reported by WOLFE & TESLER.

Conclusions

Intraluminal gastric leiomyomas are readily demonstrated by barium meal examinations. Gastric and duodenal leiomyomas are comparatively richly vascularized tumours with an accumulation of contrast medium but without arteriovenous shunts or encroachment upon vessels as demonstrated at angiography. Gastric leiomyomas or leiomyosarcomas of extraluminal extension may simulate retroperitoneal or hepatic tumours. Angiography in these cases will determine the origin and nature of the mass. The presence of large neoplastic vessels and arteriovenous shunts and vessel encroachment in gastric myomas indicate malignancy.

Rich vascularization and the presence of arteriovenous shunts occur in benign as well as in malignant intestinal growths. Larger tumours, if necrotic, may be only sparsely vascularized. However, if malignant, they always contain neoplastic vessels although arteriovenous shunts may be absent. Large size is not necessarily an indication of malignancy.

Acknowledgement

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SUMMARY

The radiographic findings in 24 gastrointestinal mesenchymal tumours (myomas and neurinomas) are reported. Special attention was paid to selective angiographic examinations. The differential diagnosis between benign and malignant leiomyomas is discussed.

ZUSAMMENFASSUNG

Die röntgenologischen Befunde bei 24 gastrointestinalen mesenchymalen Tumoren (Myomen und Neurinomen) werden beschrieben. Besondere Beachtung wurde den selektiven angiographischen Untersuchungen gewidmet. Die Differentialdiagnose zwischen benignen und malignen Leiomyomen wird diskutiert.

RÉSUMÉ

Presentation des signes radiographiques dans 24 cas de tumeur mesenchymateuse gastro-intestinale (myome et neurinome) Les auteurs ont etudie particulierement les angiographies selectives Ils examinent le diagnostic differentiel entre leiomyome benin et malin

REFERENCES

BOIJSEN E und OLIN T Zöliakographie und Angiographie der Arteria mesenterica superior *In* Ergebnisse der medizini chen Strahlenforschung p 112 Herausgegeben von H R Schinz R Glauner und A Ruttimann G Thieme Verlag Stuttgart 1964

— and REUTER S R *Mesenteric angiography in the evaluation of inflammatory and neo-*plastic disease of the intestine Radiology 87 (1966) 1028

— — Angiography in diagnosis of chronic unexplained melena Radiology 89 (1967) 413

— WALLACE S and KANTER I E Angiography in tumours of the stomach Acta radiol Diagnosis 4 (1966) 306

DEBRAY CH MORIN G *MEYMARIOS J et coll Tumeurs de l intestine grele diagnostiquées* exclusivement par l arteriographie sélective de la mesentérique supérieure Arch Mal Appar dig 54 (1965) 593

ETIENNE J P ECOIFFIER J CARBAY M et coll Leiomyosarcome du grele révélé par l arteriographie mesentérique Sem Hop Paris 47 (1971) 1169

GOLDEN TH and STOUT A P Smooth muscle tumors of the gastrointestinal tract and retro peritoneal tissues Surg Gynec Obstet 73 (1941) 784

HANNO H A and MENSCH M Leiomyoma of the jejunum Intermittent melena of fourteen years of duration and fatal hemorrhage Ann Surg 120 (1944) 199

HUGEL E Die benignen Magentumoren Radiologe 8 (1969) 257

KLEIN H J ALFIDI R J MURRAY T F and ROISIER V G Angiography in the diagnosis of *chronic gastrointestinal bleeding Radiology 98 (1971) 83*

KLOPP E J and CRAWFORD B L Leiomyoma of the small intestine Ann Surg 101 (1935) 796

LECHNER C W and CONOLLY P J Benign neoplasms of the small intestine with a report of *three bleeding benign tumors of the jejunum J Amer med Ass 169 (1959) 2003*

LEONE A J and BRYAN G S Leiomyosarcoma of the small bowel demonstrated by selective superior mesenteric angiography J Canad A s Radiol 19 (1968) 126

MEISSNER W A Leiomyoma of the stomach Arch Pathol 38 (1944) 209

MEYERS M Leiomyosarcoma of the duodenum Clin Radiol 22 (1971) 257

— and KING M C *Leiomyosarcoma of the duodenum* Angiographic findings and report of a case Radiology 91 (1968) 788

MORGAGNI cited by Neuber

NEUBER E Die Operation eines gestielten Magenmyoms Wien klin Wschr 33 (1920) 8 8

OLSSON O Angiography in the diagnosis of duodenal lesions I Differentiation between primary duodenal carcinoma and carcinoma of the head *of the* pancreas involving the duodenum Acta radiol Diagnosis 12 (1972) 49

— Angiography *in the diagnosis of duodenal lesions* II Benign tumours ulceration and inflammatory and vascular lesions Acta radiol Diagnosis 12 (1972) 164

REIFFERSCHEID M Die gutartigen Tumoren des Magens und Dunndarms Med Klin 54 (1959) 41

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, KAROLINSKA SJUKHUSET
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COORDINATE TOPOGRAPHIC RECORDINGS IN THE ABDOMEN

The ovarian artery as an indicator of the expansion of the uterus in pregnancy

by

LARS OHLSON

An investigation of the displacement of the intraperitoneal and retroperitoneal abdominal organs by the pregnant uterus suggested that certain structures moved with distinct regularity. It therefore appeared that a system of reference points was needed further to analyze this process. No such system appeared to have been used and an investigation was consequently undertaken with the relatively fixed lumbar spine and the pelvis as the sites for the reference points.

The structures that underwent change included certain vessels that possessed a number of identifiable anatomic features that appeared suitable for recording in relation to the skeletal reference points. One of these vessels, the ovarian artery, had also proved to have a circular transverse section which made it possible to determine its axis in two dimensions (BORELL et coll. 1963). This artery was therefore selected as a model for investigating the displacements of organs induced by the enlargement of the uterus in pregnancy.

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REUTER S R, REDMAN H C, MILLER W J and HOSKINS PH A Gastric angiography Radiology 94 (1970) 271

RIVER L SILVERSTEIN J and TOPE J W Benign neoplasms of the small intestine A critical comprehensive review with reports of 20 new cases Int Abstr Surg 102 (1956) 102

SCHRODER F Beitrag zur Klinik des Magenmyoms Arch klin Chir 184 (1936), 738

SHANDALOW S L Benign tumors of the small intestine Arch Surg 71 (1955) 761

VIRCHOW cited by Schroder

WOLFE S A and ELSTER J Hemorrhagic leiomyoma of small intestine simulating giant ovarian cyst Amer J Gastroent 30 (1958) 527

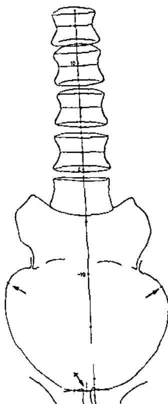


Fig 1 Topographic coordinate system Definition of skeletal reference points Scale 1 4 Midpoints of vertebral bodies and y axis indicated Origin of coordinate system (0) Pelvic inlet points (→) Symphysis (↔)

diagnostic value of the different examinations had been determined before the present investigation was undertaken

Methods The y axis was defined as a straight median line, and the true median line in the individual case as the straight lines connecting the midpoints of the narrowest transverse parts of the four upper lumbar vertebrae (Fig 1) The criterion for conformity of the true median line to the y axis was set as a maximum transverse deviation of 3 mm In those cases that fulfilled the criterion the y axis was drawn parallel to the straight line passing from the midpoint of the first to that of the fourth lumbar vertebra and equidistant between this line and the point of maximum deviation

The origin of the coordinate system was defined as the intersection of the y axis by a line drawn transversely through the centre of the inferior epiphysis of the fourth lumbar vertebra (Fig 1) This epiphysis was chosen because it was (1) better defined than the other epiphyses of the lumbar spine, (2) the most central of well defined structures in the region (3) approximately equidistant

The recordings were made in the a p plane, where any skeletal point as well as any point of the artery could be located as a pair of points in a two dimensional coordinate system The purpose of this investigation was to examine the usefulness of the coordinate system as a norm for recording the displacements of the test model

Material This consisted of arteriograms in which the ovarian artery was represented on one or both sides as arising from the aorta It comprised 57 non pregnant and 212 pregnant women, examined from 1952 to the end of 1970 Each case was examined on one occasion only The cases were divided into periods related to the duration of pregnancy and containing comparable numbers of topographic points for the statistical analysis of the positions of the ovarian artery These periods were period 0, non pregnancy, period 1, 7 to 15 weeks, period 2, 16 to 25 weeks, period 3, 25 to 29 weeks, period 4, 30 to 32 weeks, period 5, 33 to 34 weeks, period 6, 35 to 36 weeks, and period 7, 37 to 41 weeks

Twenty four cases in the non pregnant group were examined by abdominal aortography, these had no suggestion of gynaecologic disease but the remaining 33 cases in this group were examined for possible ectopic pregnancy, ovarian cyst, or uterine fibroma In 6 of these cases, arteriography and surgery disclosed tubal pregnancy These cases were included because the size of the lesion was small (less than 3 cm in diameter) and because the ovarian artery was filled only on the contralateral side In a further 14 cases, surgery confirmed normal arteriographic findings The findings again were normal in the 13 remaining cases examined for possible fibroma without later surgery The cases in period 1 were examined for ectopic pregnancy and in 2 cases hydatidiform mole but on angiography intra uterine pregnancy was found The cases in period 2 and later were examined for possible placenta praevia

The arteriographies were performed with the technique described by LERNSTROM (1955) with the patient supine and injection of the contrast medium into the abdominal aorta The FI D was 100 cm, the films being obtained at about 3, 6, and 9 seconds after the start of injection The roentgenographic projections could be divided into three categories (1) Vertical beam direction centred at the approximate level of the promontory and covering the abdominal region used for possible placenta praevia (2) Vertical beam direction centred at the approximate level of the third lumbar vertebra and covering the lumbar region, used in abdominal arteriographies (3) A caudal inclination of 15° and covering the pelvic and lower lumbar regions, used in pelvic arteriography in periods 0 and 1 A consecutive series of 182 cases from categories 1 and 2 was used for the analysis of the skeletal reference points of the topographic coordinate system

The material consisted entirely of clinical cases referred for roentgen examination on the indications mentioned Radiation doses calculated in relation to the

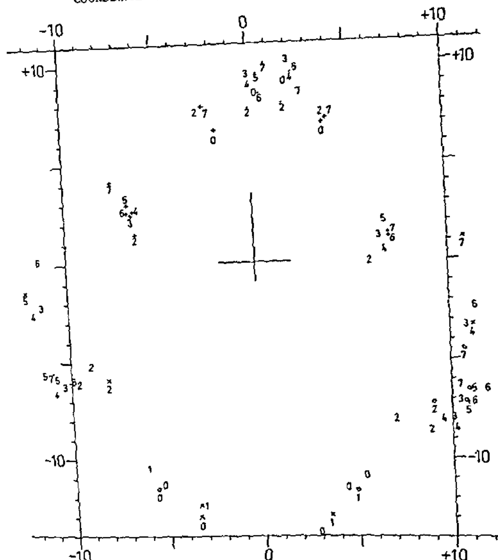
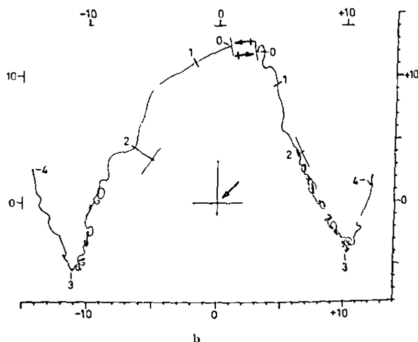


Fig 3 Changes in the course of the ovarian artery in pregnancy Statistical analysis in the *topographic* coordinate system Scale 1 2 Symbols for topographic points point 0 *point 1* + point 2 + point 3 ovary o *point* 4 x Periods of pregnancy denoted by numbers Further statistical data are given in the Table The *mean* values for the positions of the right anastomosis in period 7 and the left anastomosis in period 5 could not be included in this figure ($x = -13.3 \pm 1.0 / y = +0.7 \pm 1.8$ (n = 6) and $+12.3 \pm 1.1 / -3.8 \pm 3.1$ (n = 17) respectively)

from the central beams in categories 1 and 2 and (4) also well defined in lateral and oblique projections The centre of the epiphysis was obtained by circumscribing the most prominent parts of the epiphysis with a rectangle



a



b

Fig 2 a) Roentgenogram of characteristic course of ovarian artery in late pregnancy (34 weeks) Scale 1 3 Ovarian artery (→) b) Course record of the case in (a) Points and parts of ovarian artery indicated Origin of coordinate system (→) inner wall of aorta (↔)

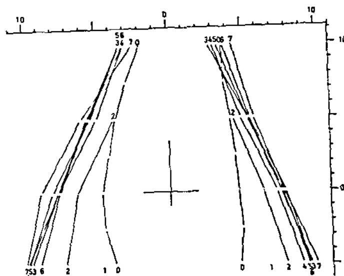


Fig 5 x coordinates of ovarian artery at different levels of y axis Scale 1 3 Periods of pregnancy denoted by numbers

by points 0 and 2 (thus including part 1) part 3 by points 2 and 3 and part 4 by points 3 and 4 The artery never extended between two consecutive points more than once

The mean values of the x and y coordinates for the artery in each period were entered as a pair of points in the coordinate system (Figs 3 4) The x coordinates were also recorded at certain levels of the y axis without regard to the location of the points (Fig 5) This recording was also used to provide approximate locations of the points for periods 0 and 1 in which the number of cases restricted the statistical analysis

The angle calculated between the perpendicular of the film plane and the beam projecting the symphysis was for category 1 about 9 and for category 3 about 15 so that the symphysis could be expected to be projected more caudally in category 3 The y coordinate of this point was therefore also determined separately for each of these categories

The course and configuration of the artery was recorded on transparent plastic sheets adapted to the coordinate system and enabling superposition of any case with any sample of other cases (Fig 7)

The statistical analysis of the course taken by the ovarian artery was performed with reference to the duration of pregnancy (Table) When the analysis of a factor resulted in significant difference between non pregnancy and pregnancy the relation of this factor to the duration of pregnancy in weeks was examined by linear regression analysis.

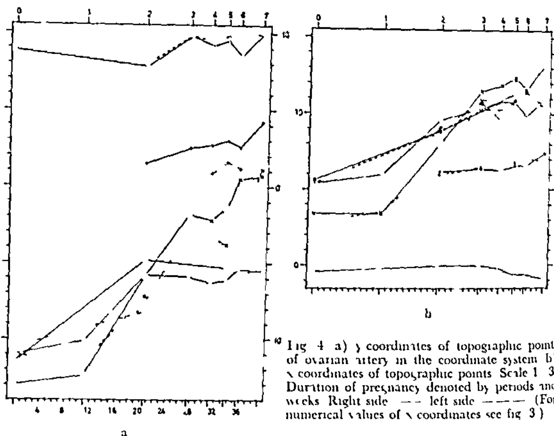


Fig. 4. a) y coordinates of topographic points of ovarian artery in the coordinate system. b) x coordinates of topographic points. Scale 1 : 3. Duration of pregnancy denoted by periods and weeks. Right side — — left side — — — (For numerical values of x coordinates see fig. 3.)

The topographic variations of the coordinate system were expressed by the standard deviations of the x and y coordinates of the following skeletal points (Fig. 1). (1) The inferior epiphysis of the first lumbar vertebra, obtained in the same way as that of the fourth lumbar vertebra. (2) The symphysis, indicated by the intersection between the longitudinal line equidistant from the most medial cortical point of the symphyseal surface of each side and the line connecting the most caudal cortical point of the superior pubic arch of each side. (3) The pelvic inlet points, defined as the most cranial and lateral cortical point on each side of the projection of the inlet.

When the median line conformed to the y axis, the axial course of the ovarian artery was determined in the following way (Fig. 2). Point 0: the intersection of the artery and the wall of the aorta. Point 1: the intersection of the artery and an arc with its centre at point 0 and a 30 mm radius. Point 2: the point of the artery equidistant from points 0 and 3. Point 3 or turning point: the most lateral point of the artery in the pelvis in periods 0 and 1 and the most caudal in later periods. The ovary: the midpoint of its hilum. Point 4 or anastomosis: the termination of the artery. Part 1 of the artery was limited by points 0 and 1, part 2



ig 6 (For legend see opposite page)

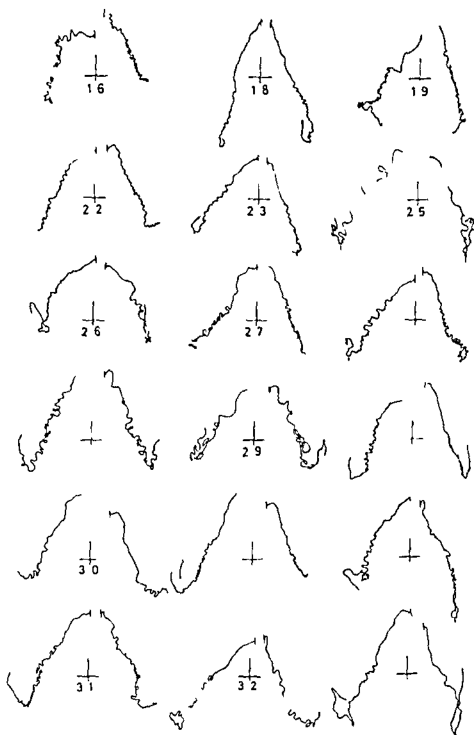


Fig 6 Single course records of ovarian artery in 36 cases Scale 1 8 Inner wall of aorta marked as in fig 2 b Duration of pregnancy in weeks indicated for the first case in each week

The course and configuration of the artery in single course records appears in Fig 6 and in superposed records in Fig 7

Discussion

Reliability of the topographic points of the ovarian artery as indicators of its course Three points of the ovarian artery were readily indentified its origin its termination and the ovary As recorded in the coordinate system two points of the artery were anatomic points — the ovary and the anastomosis — while the other points were determined geometrically Point 0 was chosen because the origin of the ovarian artery could not be exactly located by arteriography However it proved to be a reliable indicator of the site of the origin of the artery from which it was located at a small and constant distance Point 1 was selected to allow examination of the part of the artery contained on either side in the asymmetric para aortic division of the retroperitoneal space Point 2 was selected as an indicator of the consistently descending part of the artery The turning point indicated the most lateral or caudal point of the artery Since in pregnancy this point moved from the pelvis to the abdomen, it might be expected to move along the axis of the artery as well However, the ovary was consistently situated close to it hence the turning point would seem to represent approximately one and the same point of the artery throughout the series

Applicability of the coordinate system The individual variations inherent in a biologic material mean that no perfect geometric accuracy can be achieved The variations in the skeletal reference points of the topographic coordinate system must therefore be correlated to the statistical discrimination of the positions of each structure investigated by the system For the structure selected as a test model in the present investigation the ovarian artery the displacements of its topographic points in pregnancy far exceeded the variations of the coordinate system see coordinate system Fig 3 and Table) Thus the topographic coordinate system could be applied to examine the displacements of this artery The method will also be applied to other structures in following reports (OHLSON to be published)

In period 1 which involved the projection of category 3, the cranial parts of the lumbar spine were not included in the films in a sufficiently large number of cases to verify conformity with the coordinate system as could be done for the other periods Hence the points of the ovarian artery recorded in this period (which were limited to the right turning point the left ovary and the anastomoses) should not have been included They were brought in however with the above mentioned approximation of the y axis because (1) the artery in these cases was seen only in the pelvis so the approximation did not affect other

Table

Number of cases for the positions of the topographic points of the ovarian artery for each period of pregnancy Mean values ($\bar{x}$) and standard deviations (SD) of the standard deviations for the positions of the points The positions (x and y coordinates) can be measured directly in the coordinate system (figs 3 and 4)

	Period								x coordinate		y coordinate	
	0	1	2	3	4	5	6	7	$\bar{x}$	SD	$\bar{x}$	SD
Right side												
Point 0	16	0	6	6	10	13	14	6	0 4	0 1	1 7	0 5
Point 2	0	0	6	6	7	11	10	7	0 7	0 1	1 5	0 4
Point 3	13	5	11	14	23	23	15	16	1 6	0 5	2 3	0 5
Ovary	5	3	9	4	0	11	0	0	1 5		2 3	
Point 4	12	9	9	8	15	18	8	6	1 7	0 5	2 9	0 9
Left side												
Point 0	19	0	7	12	15	19	16	10	0 4	0 1	1 8	0 8
Point 2	0	0	6	8	11	15	11	9	0 9	0 [illegible]	1 7	0 6
Point 3	9	0	14	19	26	27	25	18	1 3	0 3	2 1	0 3
Ovary	14	9	11	17	11	18	12	7	1 2	0 4	[illegible]	0 5
Point 4	20	10	8	12	13	17	13	9	1 9	0 7	2 8	1 0

Results

The criteria for the y axis were satisfied in 175 of the 182 cases (96 2 per cent) The location on the y axis of the inferior epiphysis of the first lumbar vertebra was + 12 0 ± 0 4 cm (n = 94) The standard deviation of this distance was equivalent to a variation of 6 7 per cent The location of the symphysis in category 1 was x = — 0 1 ± 1 2/y = — 20 9 ± 1 8 (n = 77), and in category 3 the y coordinate for the symphysis was — 21 5 ± 1 5 (n = 42) The standard deviations for the y coordinates were equivalent to variations of 17 2 and 14 0 per cent respectively, with no significant difference between these locations For the two categories combined the y coordinate was — 21 2 ± 1 2 (n = 119), equivalent to a variation of 11 3 per cent The standard deviation range for the x coordinate was equivalent to an angle of 6 5° The location of the pelvic inlet points was — 7 4 ± 0 9/— 9 1 ± 1 2 and 6 9 ± 0 8/— 9 0 ± 1 2 (n = 99) These points were symmetric

The displacements of the ovarian arteries in different periods of pregnancy appear in Figs 3 to 7 The mean values can be measured in the coordinate system The number of cases for each period are to be found in the Table In period 1, the positive y axis could not be determined statistically therefore the median line was drawn through the symphysis the artery in this period was represented only in the pelvis so the approximation did not affect other regions

The course and configuration of the artery in single course records appears in Fig 6 and in superposed records in Fig 7

Discussion

Reliability of the topographic points of the ovarian artery as indicators of its course Three points of the ovarian artery were readily indentified its origin, its termination and the ovary As recorded in the coordinate system, two points of the artery were anatomic points — the ovary and the anastomosis — while the other points were determined geometrically Point 0 was chosen because the origin of the ovarian artery could not be exactly located by arteriography However it proved to be a reliable indicator of the site of the origin of the artery from which it was located at a small and constant distance Point 1 was selected to allow examination of the part of the artery contained on either side in the asymmetric para aortic division of the retroperitoneal space Point 2 was selected as an indicator of the consistently descending part of the artery The turning point indicated the most lateral or caudal point of the artery Since in pregnancy this point moved from the pelvis to the abdomen it might be expected to move along the axis of the artery as well However the ovary was consistently situated close to it hence the turning point would seem to represent approximately one and the same point of the artery throughout the series

Applicability of the coordinate system The individual variations inherent in a biologic material mean that no perfect geometric accuracy can be achieved The variations in the skeletal reference points of the topographic coordinate system must therefore be correlated to the statistical discrimination of the positions of each structure investigated by the system For the structure selected as a test model in the present investigation the ovarian artery, the displacements of its topographic points in pregnancy far exceeded the variations of the coordinate system (see coordinate system Fig 3 and Table) Thus the topographic coordinate system could be applied to examine the displacements of this artery The method will also be applied to other structures in following reports (OHLSON to be published)

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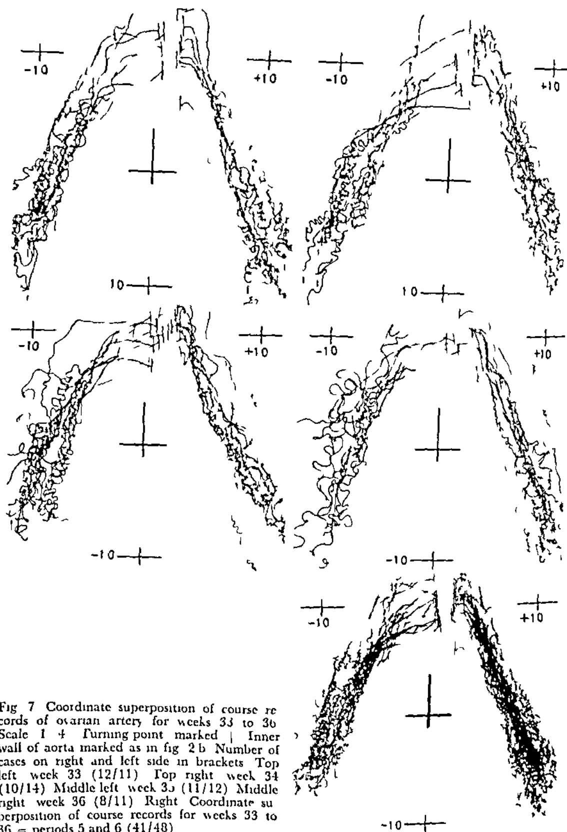


Fig 7 Coordinate superposition of course records of ovarian artery for weeks 33 to 36 Scale 1 4 Turning point marked | Inner wall of aorta marked as in fig 2 b Number of cases on right and left side in brackets Top left week 33 (12/11) Top right week 34 (10/14) Middle left week 35 (11/12) Middle right week 36 (8/11) Right Coordinate superposition of course records for weeks 33 to 36 = periods 5 and 6 (41/48)

regions and (2) the y coordinate for the symphysis coincided with that in category 1 Category 3 thus appeared in practice to be comparable with categories 1 and 2 hence consistent with the coordinate system The inclusion of this projection was necessitated by the fact that coordinate topographic recordings were not envisaged at the time these examinations were made for had this been so, category 1 would have been used throughout the series In principle the topographic imperfections of category 3 consequently do not affect the coordinate system as such

The characteristics of the topographic coordinate system will be apparent by comparing the system with the two conventional space time diagrams in Fig 4 Each of these contains one spatial parameter presented in a two-dimensional coordinate system where the linear time parameter occupies the other dimension Each spatial parameter was derived from the location of one point in the frontal plane This mode of presentation being spatially one dimensional does not represent the topographic location of a point The two-dimensional reconstruction of the location of a point by means of these diagrams thus requires the inverse procedure of plotting one of the spatial parameters in one diagram This may be done mentally for a limited number of points but a complex pattern of points requires the plotting of a graph particularly when measurements are to be made The topographic coordinate system reconstitutes the location of each point as a pair of points in a system where both the x and y axes are spatial it thus combines the two space time diagrams into one graph The linear time parameter could be dispensed with as a dimension and be denoted by the numbers of the periods of pregnancy Thus, the movements of a given point can be analyzed by following the pattern of points denoted by the time symbol simultaneously giving the combined information of the two diagrams mentioned and the possibility of congruent measuring of locations distances directions etc It thus involves the initial procedure of correlating a point to conventional reference points in a roentgen film as well as the reconstitution of a given location into a pair of points for an optional number of cases

The characteristics of the coordinate superposition will be apparent from Figs 2 6 and 7 The single course records (Figs 2 6) represent the positions of the topographic points in each case as introduced into the coordinate system as well as the configuration of the artery between the points The sum of the course records thus contains the information recorded in the coordinate system (i e the course of the artery as defined by the topographic points) plus the configuration of the artery Since every single case is recorded separately on its transparent plastic sheet the course and configuration of any artery may be compared to those of any other artery for a given purpose This method thus enables a direct visual comparative analysis of a set factor such as the duration of pregnancy or the width or length of the artery Coordinate superposition of course records

reveals the degree of consistency of the course and the configuration of the ovarian artery. It may be applied analogously to the position and shape of any other structure.

The need for complementary recordings in the sagittal plane appears in principle to be inversely proportional to the anatomic regularity of a structure. Topographic recordings may consequently be divided into two categories. (1) Structures with a well defined anatomy exhibiting small individual variations, for which the need for complementary lateral projection is small, irrespective of their extent in the sagittal plane. This category would include such structures as the lumbar spine and the pelvic skeleton, the aorta and the lumbar arteries, the iliac arteries and their branches, the inferior vena cava and its tributaries, the ovarian vessels and the inferior mesenteric vessels in the posterior abdominal wall as well as the ureter. (2) Structures exhibiting marked individual variations that increase the need for lateral projection, such as the uterine artery and its branches, the cranial parts of the round ligament artery, the distal parts of the ovarian vessels running in the peritoneal folds of the uterus, the sigmoid branches of the inferior mesenteric vessels in pregnancy, and the branches of the superior mesenteric artery and vein.

Lateral roentgenograms during late pregnancy permitted the course of the ovarian artery in the sagittal plane to be recorded and measured, but the number of cases was too small to permit statistical analysis of its course in this plane. In the a.p. projection its course in the sagittal plane could not be measured although it could be determined by relating it to other structures such as the uterine artery and its branches, the round ligament artery, the uterine wall, the inferior mesenteric artery and its branches, and the abdominal wall in late pregnancy. The information contained in the a.p. projection thus also provided unequivocal general topographic information about locations in the sagittal plane where measurements could not be made.

The two methods described, i.e. the coordinate system and the coordinate superposition, may be applied to any structure in the abdominal region. For structures limited to the lumbar region a more cranial location of the origin of the coordinate system will provide greater accuracy, the difference will be small (1 to 2 mm), but may naturally be of importance for recordings of small distances. The methods will be applied to determine the non-pregnant and pregnant topography of the following structures in later reports.

The course of the ovarian vein proved to coincide with that of the ovarian artery. The ureter was displaced in pregnancy but in a way distinct from that of the ovarian vessels. The inferior mesenteric artery was displaced in pregnancy.

The uterine wall in the present context was recorded at the longitudinal levels of the turning point and the anastomosis of the ovarian artery. The uterus was

dextroverted in late pregnancy whereas there was no significance for rotation of the organ

The abdominal arteriograms the arteriograms used for localization of the placenta and the urograms in the present investigation, were also analyzed as to the following structures The number of cases examined in the lateral projection permitted a statistical analysis of their location and configuration in the sagittal as well as the a p plane Detailed results of these investigations will be presented later

The aorta was displaced to the left side (and compressed) by the pregnant uterus The lumbar arteries were also displaced (and compressed) in pregnancy The development in pregnancy of the course and configuration of the uterine artery and its branches was recorded in relation to the uterine wall and to the position the size and the shape of the placenta. The course and length of the round ligament artery changed with the displacement in pregnancy of its anastomoses with the uterine and ovarian arteries

The normal non pregnant course of the ureter was determined This enabled the demonstration of pathologic displacements as by tumours and other retro peritoneal and intraperitoneal masses and by the urinary bladder The lumbar spine deviated slightly but significantly from the y axis in the supine position

SUMMARY

The ovarian artery was regularly displaced in pregnancy The topographic constancy of certain skeletal structures in the abdominal region was examined to correlate the dis placement to a system of reference points This enabled statistical determination of the dis placements of the artery to be made in a two dimensional topographic coordinate system the use of which is discussed in the a sessment of normal and pathologic changes in the posi tion of intraperitoneal and retroperitoneal organs

ZUSAMMENFASSUNG

Die Ovarialarterie zeigte wahrend der Gravidität stets eine veränderte Lage Die topographische Konstanz gewisser Skelettstrukturen der abdominalen Region wurde unter sucht um die abweichende Lage auf ein System von Referenzpunkten beziehen zu können. Diese ermöglichten statistisch die Lageveränderungen der Arterie in einem zweidimensionalen topographischen Koordinatensystem zu bestimmen, dessen Anwendung bei der Beur teilung normaler und pathologischer Lageveränderungen der intraperitonealen und retro peritonealen Organe diskutiert wird

RÉSUMÉ

L artère ovarienne est toujours deplacée au cours de la grossesse L auteur a étudié la constance topographique de certaines structures squelettiques de la région abdominale pour rapporter le déplacement de l artère ovarienne a un système de points de référence Ceci a

reveals the degree of consistency of the course and the configuration of the ovarian artery It may be applied analogously to the position and shape of any other structure

The need for complementary recordings in the sagittal plane appears in principle to be inversely proportional to the anatomic regularity of a structure Topographic recordings may consequently be divided into two categories (1) Structures with a well defined anatomy exhibiting small individual variations, for which the need for complementary lateral projection is small, irrespective of their extent in the sagittal plane This category would include such structures as the lumbar spine and the pelvic skeleton, the aorta and the lumbar arteries, the iliac arteries and their branches, the inferior vena cava and its tributaries, the ovarian vessels and the inferior mesenteric vessels in the posterior abdominal wall as well as the ureter (2) Structures exhibiting marked individual variations that increase the need for lateral projection, such as the uterine artery and its branches, the cranial parts of the round ligament artery, the distal parts of the ovarian vessels running in the peritoneal folds of the uterus, the sigmoid branches of the inferior mesenteric vessels in pregnancy, and the branches of the superior mesenteric artery and vein

Lateral roentgenograms during late pregnancy permitted the course of the ovarian artery in the sagittal plane to be recorded and measured, but the number of cases was too small to permit statistical analysis of its course in this plane In the a p projection its course in the sagittal plane could not be measured although it could be determined by relating it to other structures, such as the uterine artery and its branches, the round ligament artery, the uterine wall, the inferior mesenteric artery and its branches and the abdominal wall in late pregnancy The information contained in the a p projection thus also provided unequivocal general topographic information about locations in the sagittal plane where measurements could not be made

The two methods described i e the coordinate system and the coordinate superposition, may be applied to any structure in the abdominal region For structures limited to the lumbar region a more cranial location of the origin of the coordinate system will provide greater accuracy, the difference will be small (1 to 2 mm), but may naturally be of importance for recordings of small distances The methods will be applied to determine the non pregnant and pregnant topography of the following structures in later reports

The course of the ovarian vein proved to coincide with that of the ovarian artery The ureter was displaced in pregnancy but in a way distinct from that of the ovarian vessels The inferior mesenteric artery was displaced in pregnancy

The uterine wall in the present context was recorded at the longitudinal levels of the turning point and the anastomosis of the ovarian artery The uterus was

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BALLOON CATHETERS IN ANGIOGRAPHY

An experimental investigation in rabbits

by

R JENSEN and T OLIN

Small balloon catheters of reliable quality and suitable for percutaneous introduction into human blood vessels have recently been developed (NORDENSTRÖM 1962 WHOLEY et coll 1970) A general survey in animals of the possible application of such catheters to roentgenology was consequently considered timely

Material and Methods Twenty five rabbits were anaesthetised with intravenous pentobarbitone sodium (Mebumalnatrium ACO Sweden) Various catheters were introduced by a cut down technique from the femoral artery the carotid artery or the right superficial jugular vein The arteries were catheterized with a polythene catheter OPP 60 (Portex England OD/ID = 1 22/0 76 mm) as described earlier (ADAMS et coll 1965) The veins were catheterized with a polyvinyl catheter RO I (Portex England OD/ID = 1 6/0 85 mm) with three large side holes close to the tip Small balloon catheters to suit the arteries of the

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permis de faire une etude statistique des deplacements de l artere dans un systeme de co ordonnees topographiques bidimensionnelles dont l utilisation est etudiee pour apprecier la position normale et les deplacements pathologiques des organes intrapéritoneaux et retro peritoneaux

REFERENCES

BORELL U FERNSTROM I and OHLSON L Diagnostic value of arteriography in cases of placenta praevia Amer J Obstet Gynec 86 (1963) 535

FERNSTROM I Arteriography of the uterine artery Acta radiol (1955) Suppl No 122

OHLSON L Non pregnant anatomy of the posterior abdominal wall as reflected in the course of the ovarian vessels and ureter Roentgenographic statistical and anatomic investigation To be published in Acta radiol Diagnosis

— Ovarian vessels and ureter as indicators of the expansion of the uterus in pregnancy Roentgenographic and statistical investigation To be published in Acta radiol Diagnosis

portal vein and the renal artery and vein The vessels in the neck included the right common carotid artery the innominate artery and the left vertebral artery

An outline of the different experiments is given below

Visceral circulation

	Coeliac trunk	Superior mesenteric artery	Hepatic vein	Superior mesenteric vein
Exp No 1	Injection	Occlusion	—	—
Exp No 2	Occlusion	Injection	—	—
Exp No 3	Occlusion	Occlusion	Injection	—
Exp No 4	Occlusion	—	—	Injection
Exp No 5	—	Occlusion	—	Injection
Exp No 6	Occlusion	Occlusion	—	Injection

Renal circulation

	Renal artery	Renal vein
Exp No 7	Occlusion	Injection

Cerebral circulation

	Right common carotid artery	Innominate artery	Left vertebral artery
Exp No 8	Occlusion	—	Injection
Exp No 9	—	Occlusion	Injection

Results

Visceral circulation When the superior mesenteric artery was occluded and the injection made into the coeliac axis (experiment 1) the diameter of the common hepatic artery as well as that of the proper hepatic artery increased by about 50 per cent and the density of the liver increased (Fig 2) Small collaterals from the coeliac axis to the superior mesenteric artery were usually evident The concentration of contrast medium in the portal vein (filled from the gastric veins) increased when the superior mesenteric artery was occluded No retrograde filling of portal branches from the hepatic artery was observed

Superselective injection into the common hepatic artery revealed that the caliber of the hepatic arteries was larger and the density of the liver greater than when the injection was made into the coeliac axis Occlusion of the superior mesenteric artery influenced the appearances to only a minor extent with injection into the common hepatic artery

The coeliac axis was occluded and the superior mesenteric artery injected (experiment 2) The concentration of contrast medium in the upper part of the portal vein was higher and the ramification of the portal veins in the liver was better demonstrated and wider than in the nonocclusion experiment (Fig 3)

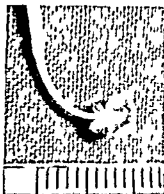


Fig. 1. Balloon catheter of 0.1 ml capacity used in the experiments.

rabbit were made in the following way: a polythene catheter (OPP 60) was heated over a hot air gun (OLIN 1963), tapered, and shaped for the vessel to be catheterized; the end of the tapered tip was then cautiously heated over a flame so that a small flange was produced, a piece of thin rubber membrane (from a condom) being then tied over the flanged tip with Ethicon 4—0 (Fig. 1). Before tightening the knot, the catheter was filled with a water soluble contrast medium. Different sizes of balloon may be made by this method. If the rubber sheet be stretched across the slightly flanged end, a balloon sufficiently large for the coeliac trunk and the superior mesenteric and renal arteries is obtained. The balloon, due to the elasticity of the rubber, empties as soon as the stopcock at the other end of the catheter is opened. The catheter ought not to contain air or the expansion of the balloon on injection will be unreliable; a small 1 ml syringe is used, the volume that had to be injected to block one of the larger arteries being about 0.05 ml.

Catheters for occlusion or injection were introduced into the vessels with the aid of magnification fluoroscopy. The injection of contrast medium was performed with a high pressure injector (VeReCe, Kistner, Sweden), the flow rate of the injection being recorded on one of the channels of a polygraph by a linear potentiometer. Series of films were exposed with twofold magnification (FFD 90 cm), tube focus 0.3 mm, high definition screens (Rubin, Siemens, Germany) but no grid were used in the film changer (AOT, Elema Schonander, Sweden) run at suitable speed. Usually 3 to 10 mAs (0.03 to 0.08 s) and 85 to 100 kV gave an adequate exposure with a medium sized rabbit. Contrast medium (Isopaque Cerebral) was injected into a specific vessel at a chosen rate with or without occlusion of another vessel. The following abdominal vessels were examined: the coeliac trunk, the superior mesenteric artery, the hepatic vein, the

a b

Fig 3 Angiography of the superior mesenteric artery Venous phase a) Normal b) Balloon occlusion of the coeliac axis Increased caliber of the portal vein (→) The coeliac axis is filled with contrast medium through collaterals



Fig 4 Angiography of the superior mesenteric artery Arterial phase Balloon occlusion of the coeliac axis Collaterals (→) to the coeliac axis

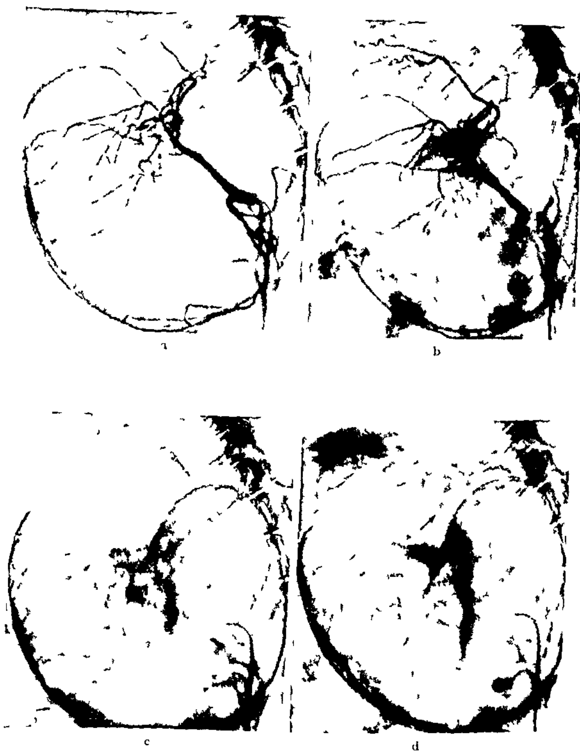


Fig 2 Coeliac axis angiography a) Arterial phase Normal b) Arterial phase Balloon occlusion of the superior mesenteric artery Increased caliber of the hepatic artery (→) c) Venous phase Normal d) Venous phase Balloon occlusion of the superior mesenteric artery Somewhat increased filling of the portal venous system and slightly diminished caliber (→)

a b

Fig 3 Angiography of the superior mesenteric artery Venous phase a) Normal b) Balloon occlusion of the coeliac axis Increased caliber of the portal vein (→) The coeliac axis is filled with contrast medium through collaterals



Fig 4 Angiography of the superior mesenteric artery Arterial phase Balloon occlusion of the coeliac axis Collaterals (→) to the coeliac axis



Fig. 5. Angiography of the superior mesenteric vein. a) Normal. b) Balloon occlusion of the coeliac axis. Increased caliber of the portal vein and its branches.

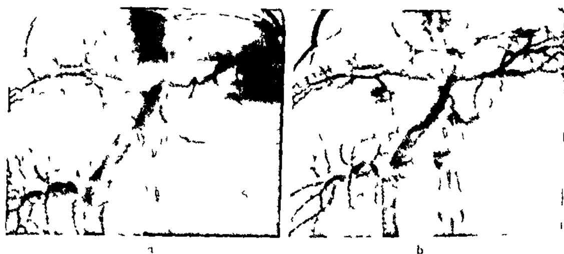


Fig. 6. Angiography of the superior mesenteric vein. a) Normal. b) Balloon occlusion of the superior mesenteric artery. Diminished caliber of the portal vein and its branches.

The filling of the portal system was, however, not as good as in experiment 1. Small collaterals from the superior mesenteric artery to the coeliac axis were usually present (Fig. 4). The caliber of the superior mesenteric artery and its branches failed to change on occlusion of the coeliac axis.

Contrast medium was injected into the hepatic vein at the same time as the coeliac axis and superior mesenteric artery were occluded (experiment 3). The

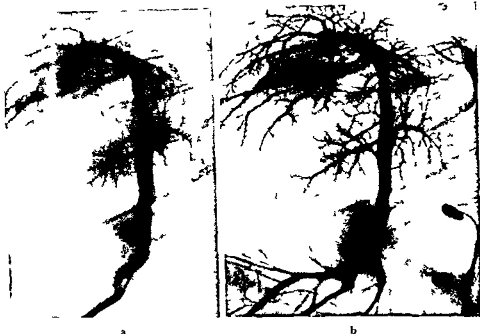


Fig 7 Angiography of the superior mesenteric vein a) Normal b) Balloon occlusion of the coeliac axis and superior mesenteric artery Much contrast medium in the vein and excellent filling of small branches Retrograde flow into the superior mesenteric vein

contrast medium sometimes filled the branches of the vein better than in the nonocclusion experiments The decisive factor however was the position of the catheter in the hepatic vein

The coeliac axis was occluded and the superior mesenteric vein injected (experiment 4) Less dilution of contrast medium in the portal ramification in the liver was then evident (Fig 5) No retrograde flow in the mesenteric vein occurred at the injection rates used The caliber of the portal vein and its branches increased by about 50 per cent on occlusion of the coeliac axis

The superior mesenteric artery was occluded and the injection made into the superior mesenteric vein (experiment 5) The caliber of the portal ramification in the liver was diminished (Fig 6) Slight backflow in the superior mesenteric vein often occurred on occlusion of the superior mesenteric artery

Simultaneous occlusion of the superior mesenteric artery and the coeliac axis and injection into the superior mesenteric vein formed experiment 6 Practically no dilution of contrast medium occurred and the demonstration even of the fine portal branches was excellent (Fig 7) Retrograde flow of contrast medium

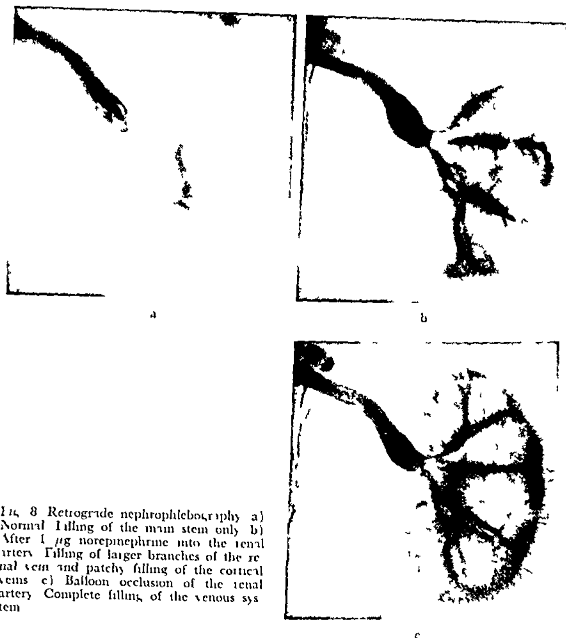


Fig. 8. Retrograde nephrophlebography. a) Normal. Filling of the main stem only. b) After 1 μg norepinephrine into the renal artery. Filling of larger branches of the renal vein and patchy filling of the cortical veins. c) Balloon occlusion of the renal artery. Complete filling of the venous system.

into the superior mesenteric vein occurred with next to no dilution. The caliber of the portal vessels increased with the rate of injection. The angiogram resembled that obtained on filling of the vessels of a specimen.

Renal circulation. Retrograde injection of contrast medium into the renal vein produced filling only of the first part of the vein stem and sometimes its first branches (Fig. 8 a). If the blood flow through the kidney were diminished by an injection of 1 μg norepinephrine into the renal artery (20 s before the



Fig 9 Angiography of the left vertebral artery a) Normal Some retrograde flow into the right vertebral artery Filling of the posterior part of the circle of Willis b) Balloon occlusion of the right common carotid artery Practically no retrograde flow into the right vertebral artery Filling of the right half of the circle of Willis and retrograde flow into the internal carotid artery to the common carotid artery (→)

angiography) better filling of the renal vein was obtained (Fig 8 b) The filling was however patchy and some branches in the periphery remained unfilled If the injection into the vein were made when the artery was occluded with a balloon (experiment 7) however complete filling of the venous system out into the cortex occurred (Fig 8 c)

Cerebral circulation Injection into the left vertebral artery produced filling of the basilar artery and the posterior part of the circle of Willis If the speed of injection were high enough slight retrograde filling of the upper part of the right vertebral artery was also obtained (Fig 9 a) Occlusion of the right common carotid artery (experiment 8) prevented filling of the right vertebral artery despite an unchanged injection rate (Fig 9 b) The vascular territory of the right internal carotid artery was outlined via the posterior part of the circle of Willis and the external carotid artery and its branches were filled through retrograde flow in the internal carotid artery

If the innominate artery (the common trunk for the right subclavian and right common carotid arteries) was occluded at left vertebral angiography (experiment 9) filling of the posterior part of the circle of Willis was less than in nonocclusion angiography (Fig 10) Widening of the vertebral arteries and retrograde flow of contrast medium through the right vertebral artery down to the level of the right subclavian artery was evident from here the contrast medium flowed into that artery as well as up into the right common carotid artery In one experiment the balloon catheter lay in the right subclavian artery at the origin of the right vertebral artery retrograde filling of only the upper two-thirds of the right vertebral artery occurred

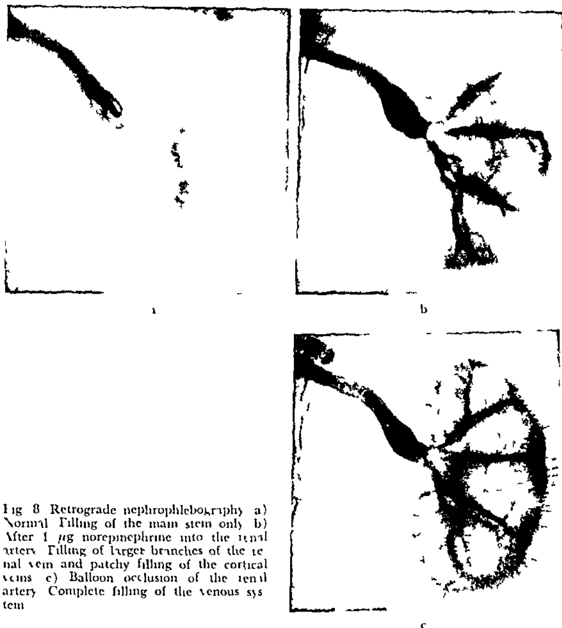


Fig. 8. Retrograde nephrophlebography. a) Normal. Filling of the main stem only. b) After 1 μg norepinephrine into the renal artery. Filling of larger branches of the renal vein and patchy filling of the cortical veins. c) Balloon occlusion of the renal artery. Complete filling of the venous system.

into the superior mesenteric vein occurred with next to no dilution. The caliber of the portal vessels increased with the rate of injection. The angiogram resembled that obtained on filling of the vessels of a specimen.

Renal circulation. Retrograde injection of contrast medium into the renal vein produced filling only of the first part of the vein stem and sometimes its first branches (Fig. 8 a). If the blood flow through the kidney were diminished by an injection of 1 μg norepinephrine into the renal artery (20 s *before* the

the hepatic artery and the portal vein of the dog also with a thermoelectric method He discovered that these flows often reacted inversely, if he diminished *the portal flow in one* way or another, the flow increased in the hepatic artery The experiments cited indicate that the hepatic arterial flow will increase when the portal flow is obstructed, which is in accordance with the present angiographic findings Transillumination investigations of the liver in the frog and rat have disclosed that occlusion of the portal vein fails to stop the flow through the liver (SENEVIRATNE 1949) No reversal of flow from the hepatic artery to the portal vein was revealed at angiography in animals with normal vascular anatomy of the liver Such a flow has however been described in hepatic cirrhosis (CHENDEROVITCH 1956) When the injection of contrast medium was made superselectively into the hepatic artery the caliber of the artery and its branches rose as compared with when it was made into the coeliac axis (ALMEN 1966) This probably represented distension of the hepatic artery caused by forced injection Occlusion of the superior mesenteric artery will not much influence such an angiography

When the coeliac artery was occluded and the injection made into the superior mesenteric artery (experiment 2) the concentration of contrast medium in the widened portal vein and its branches was satisfactory This may probably be interpreted as an increase in portal blood flow GINSBURG & GRAYSON (1954) reported that when the coeliac axis was occluded in rats the total liver blood flow fell to a mean of 67 per cent of its original level this was followed by a recovery to a mean of 82 per cent of the original flow within eight minutes after the ligation REIN (1943) measured the hepatic arterial flow and the portal vein flow in dogs and stated that the portal flow increased when the hepatic artery was occluded These experiments are in accordance with the present angiographic evaluation The increased concentration of contrast medium in the portal circulation is probably due to diminished dilution from the splenic and gastric veins brought about by occlusion of the coeliac axis

Balloon occlusion of the coeliac axis at angiography of the superior mesenteric artery may be tried clinically in the investigation of disease of the portal system *It should be* compared to or combined with pharmacoangiography with bradykinin (BOIJSEN & REDMAN 1966) A draw back of the balloon occlusion method, when the portal venous system is examined from the arterial side, is the increase in the vascular volume of this system which occurs on occlusion of the coeliac axis which *in turn increases the dilution of contrast medium* Before dearterialization of the liver the potential collaterals may be evaluated by preoperative balloon occlusion angiography e g a small amount of contrast medium is injected into the hepatic artery peripherally to the balloon The washout of contrast medium from the hepatic artery is followed by serial angiography



Fig. 10. Angiography of the left vertebral artery. a) Normal. Slight retrograde flow into the right vertebral artery. Filling of the posterior part of the circle of Willis. b) Balloon occlusion of the innominate artery (→). Increased flow into the vertebral artery and retrograde flow into the right vertebral artery down to the subclavian artery. The right common carotid artery is also filled through the vertebral artery. The posterior part of the circle of Willis is not outlined.

Discussion

Visceral circulation. Occlusion of the superior mesenteric artery and injection into the coeliac artery (experiment 1) produced an increase in flow in the hepatic artery which was probably compensatory. Ginsburg & Grayson (1954) measured the total blood flow of the liver in rats by a thermoelectric method (internal calorimetry). Occlusion of the portal vein produced a fall in the blood flow to 40 per cent of the original level and then a rise to 50 per cent of the resting flow. Sancetta (1953) measured the flow in the hepatic artery of the dog with a photoelectric bubble flowmeter; occlusion of the portal vein caused a steep rise in the hepatic arterial flow. Schwiegk (1953) obtained the blood flow in both

the hepatic artery and the portal vein of the dog also with a thermoelectric method. He discovered that these flows often reacted inversely, if he diminished the portal flow in one way or another, the flow increased in the hepatic artery. The experiments cited indicate that the hepatic arterial flow will increase when the portal flow is obstructed, which is in accordance with the present angiographic findings. Transillumination investigations of the liver in the frog and rat have disclosed that occlusion of the portal vein fails to stop the flow through the liver (SENEVIRATNE 1949). No reversal of flow from the hepatic artery to the portal vein was revealed at angiography in animals with normal vascular anatomy of the liver. Such a flow has, however, been described in hepatic cirrhosis (CHENDEROVITCH 1956). When the injection of contrast medium was made superselectively into the hepatic artery, the caliber of the artery and its branches rose as compared with when it was made into the coeliac axis (ALMEN 1966). This probably represented distension of the hepatic artery caused by forced injection. Occlusion of the superior mesenteric artery will not much influence such an angiography.

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Balloon occlusion of the coeliac axis at angiography of the superior mesenteric artery may be tried clinically in the investigation of disease of the portal system. It should be compared to or combined with pharmacoangiography with bradykinin (BOIJSEN & REDMAN 1966). A drawback of the balloon occlusion method when the portal venous system is examined from the arterial side is the increase in the vascular volume of this system which occurs on occlusion of the coeliac axis, which in turn increases the dilution of contrast medium. Before dearterialization of the liver the potential collaterals may be evaluated by preoperative balloon occlusion angiography, e.g. a small amount of contrast medium is injected into the hepatic artery peripherally to the balloon. The washout of contrast medium from the hepatic artery is followed by serial angiography.



Fig 10 Angiography of the left vertebral artery a) Normal Slight retrograde flow into the right vertebral artery Filling of the posterior part of the circle of Willis b) Balloon occlusion of the innominate artery (→) Increased flow into the vertebral artery and retrograde flow into the right vertebral artery down to the subclavian artery The right common carotid artery is also filled through the vertebral artery The posterior part of the circle of Willis is not outlined

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and of the liver could be obtained The intriguing haemodynamics of the liver in cirrhosis hepatoma and other diseases might be evaluated by angiography combined with balloon occlusion of one of the feeding vessels No backflow from the hepatic artery to the portal vein will occur with a moderate degree of hepatic cirrhosis If, however the superior mesenteric artery be occluded such a flow might be revealed at angiography as an early sign of changed vascular anatomy of the liver Occlusion of either the coeliac axis or the superior mesenteric artery and injection into the portal system produces excellent angiograms that may be of value if detailed analysis of the liver be desired The caliber of the portal vein depends on the injection rate and may be altered at will The method of using a balloon catheter to occlude the coeliac or the superior mesenteric artery may be used therapeutically for arresting bleeding in the oesophagus stomach and intestines (WHOLEY et coll 1970) When the blood pressure is lowered locally and the flow velocity diminished a thrombus may develop in the affected vessel and attach itself to the vessel wall

Renal circulation The arterial blood flow to the kidney in retrograde nephrophlebography has to be obstructed so that the contrast medium may be forced out into the small veins of the cortex The method of HAVERLING (1966) entailing general anaesthesia increased intrathoracic pressure and balloon occlusion of the aorta and inferior vena cava is too complicated to be used routinely The pharmacoangiographic method of improving phlebography by injecting a vasoconstrictor into the renal artery immediately before the injection of contrast medium into the vein (OLIN & REUTER 1965) is much easier to use although it possesses certain disadvantages The filling of the small veins of the cortex is often incomplete In the presence of arteriovenous shunts (carcinoma arteriovenous shunts haemangioma) the filling of the shunting veins is also incomplete as the blood flow through these shunts is not reduced sufficiently by the pharmaceutic agents (ABRAMS 1964) Retrograde injection into the renal vein following occlusion of the renal artery by a balloon catheter ought therefore to be a useful method in clinical work providing that only one renal artery exists This balloon technique should be compared with occlusion on the venous side (THALHEIMER & GILLOT 1962 TAKARO et coll 1970) Balloon occlusion of the artery may be of therapeutic value in cases of bleeding from the kidney when no other method can be used e g in inoperable carcinoma (WHOLEY et coll 1970)

Cerebral circulation Experiments (8 and 9) indicated that the circulation may rapidly be altered in the vertebral and basilar arterial system and in the circle of Willis. (Compare MACDONALD & POTTER 1951) The marked increase in the

One phenomenon on occlusion of an artery that has not been investigated is reactive hyperemia, this latter may be of clinical value If, for example, the coeliac axis be occluded for five minutes and the occlusion then released, reactive hyperemia occurs (GINSBURG & GRAYSON 1954), contrast medium injected will rapidly be carried away during this phase Tumour vessels are known to react less to vasoconstrictor agents (ABRAMS 1964) and the same probably holds true for vasodilators A rapid flow of contrast medium will thus occur from normal structures although not from tumour structures during reactive hyperemia (compare the slow infusion technique for hepatic angiography described by VIRTAMA 1970)

Somewhat better filling of the veins was sometimes obtained by occlusion of the coeliac and superior mesenteric arteries and retrograde injection of contrast medium into the veins of the liver This increase in quality was not consistently obtained, however, and the method cannot be recommended for clinical application Retrograde injection of contrast medium into the veins of the liver without occlusion of the arteries has been used in Japan (NAKAMURA et coll 1959, 1969) Better filling of the veins is obtained if the balloon catheters be used on the venous side with occlusion of a segment of the inferior vena cava and injection between the balloons (THALHEIMER & GILLOT 1962) NORHAGEN (1963) tried a variation of this technique utilizing single balloon occlusion of the inferior vena cava at its inlet into the right atrium, combined with compression (increased intrabronchial pressure) of the liver followed by rapid decompression The balloon occlusion technique on the venous side with one or two balloons is probably the method of choice for examining the hepatic veins The reason why balloon occlusion of the coeliac axis and superior mesenteric artery rather fails to improve hepatic phlebography is probably largely due to the fact that the pressure in the hepatic veins is low even without occlusion Of crucial importance, however, is the injection technique on the venous side

Injection of contrast medium directly into the portal system during occlusion of one or both of the two main arteries (superior mesenteric and coeliac arteries, experiments 4, 5 and 6), produced a decrease in its dilution in the liver and portal system Occlusion of the coeliac axis caused an increase in caliber of the portal vein and its branches (experiment 4) This was probably compensatory dilatation (compare references cited earlier in this paper, experiment 2) The propagation of contrast medium through the portal system was slowed down and the caliber of the vessels diminished when the superior mesenteric artery was occluded (experiment 5) This was due to diminished flow as well as to decreased pressure in the portal system The dilution of contrast medium in the portal system at splenoportography would be diminished if the superior mesenteric artery were occluded, and thus a better evaluation both of the collaterals

SUMMARY

Various arteries in the rabbit have been occluded by balloon catheters Contrast medium was injected into adjacent vessels and the changed haemodynamics investigated by angiography The various mechanisms brought into action with this technique are discussed and certain clinical applications are suggested

ZUSAMMENFASSUNG

Verschiedene Arterien beim Kaninchen wurden mittels Ballonkatheter verschlossen Es wurde Kontrastmittel in die angrenzenden Gefasse injiziert und die veranderte Hamodynamik mit Angiographie untersucht Es werden die verschiedenen Mechanismen die durch diese Technik hervorgerufen werden diskutiert und gewisse klinische Anwendungen vorgeschlagen

RÉSUMÉ

Les auteurs ont obstrue differentes arteres chez le lapin au moyen de sonde a ballonnet Ils ont injecte un moyen de contraste dans les vaisseaux adjacents et ont etudie par angiographie les modifications de l hemodynamique Ils examinent les differents mecanismes mis en jeu par cette technique et proposent certaines applications cliniques

REFERENCES

Abrams H L The response of neoplastic renal vessels to epinephrine in man Radiology 82 (1964) 217

Adams D Olin T and Redman H Catheterization of arteries in the rabbit Radiology 84 (1965) 531

Almen T A steering device for selective angiography and some vascular and enzymatic reactions observed in its clinical application Acta radiol (1966) Suppl No 260

Boijsen E and Redman H Effect of bradykinin on celiac and superior mesenteric angiography J invest Radiol 1 (1966) 422

Chenderovitch J et Caroli J La microangioradiographie du foie et de la rate Rev int Hépat. 6 (1956) 907

Ginsburg M and Grayson J Factors controlling liver blood flow in the rat J Physiol 123 (1954) 574

Haverling M Renal phlebography An experimental study in the pig Acta radiol (1966) Suppl No 251

Jacobsson B Use of Dextran in prophylaxis against thromboembolic complications in arterial catheterization Acta chir scand (1968) Suppl No 387 p 103

Kessler L A and Wholey M H Internal carotid occlusion for treatment of intracranial aneurysms A new percutaneous technique Radiology 95 (1970) 581

Mac Donald D A and Potter J M The distribution of blood to the brain J Physiol 114 (1951) 356

Nakamura T Nakamura S Onodera A Aikawa T and Iida H Hepatic venography in hepatic tumours. Tohoku J exp Med 99 (1969) 281

calibre of the vertebral artery following subclavian artery steal appeared without delay The experiments described represent a simple means of investigating the principles of collateral circulation and the factors regulating these mechanisms The occlusion method has been employed for a long time in cerebral angiography to demonstrate aneurysms in different parts of the circle of Willis Thus compression of the carotid artery on the opposite side is performed to fill an aneurysm of the anterior communicant at carotid angiography and is carried out by digital compression of the vessel In clinical work, the balloon catheter method would be of value as a test of the capacity of the collateral circulation to the brain before planned occlusion of some of its larger feeding vessels The method could be used therapeutically to increase the possibility of thrombus formation in an aneurysm by changing the direction of flow and diminishing the velocity of the blood The advantage of the balloon as opposed to the tourniquet method is the relatively atraumatic nature of the former and the ease with which the volume of the balloon may be adjusted (KESSLER & WHOLEY 1970)

The risks involved in the use of balloon catheters of modern type are fairly small, provided that the period of occlusion be short If the balloon be over distended it will change from a sphere to a cylinder, which is easily revealed by fluoroscopy Undue distension of the balloon may cause vessels to form an aneurysm or to rupture This will only occur on crude handling, but for safety the authors have started a control investigation in rabbits after deliberately over distending the balloon in different arteries

Ischaemia is not well tolerated in the central nervous system, but the collateral circulation via the circle of Willis is effective and if any sign of cerebral ischaemia occurs when the carotid or subclavian artery is occluded it is easy to empty the balloon The kidney may be deprived of its blood supply for some minutes without any adverse effects (PORCH et coll 1960) The liver can also tolerate some minutes of ischaemia, especially if arterial collaterals exist and if only one of the main feeding vessels be occluded The bowel is relatively insensitive to a reasonable degree of ischaemia Further investigations on the risks of ischaemia when balloon occlusion is used may be carried out by estimating the level of specific enzymes in the blood and urine

A thrombus may form around balloon catheters, especially if a long piece of catheter lies in the blood stream for some time This may be prevented by premedication with dextran (Macrodex, Pharmacia, Sweden, JACOBSSON 1968) It is most important that the surface of the balloon catheter should be smooth and even, since a rough surface tends to produce clotting, modern balloon catheters, e g those from Edwards Laboratories, California, USA, fulfil these demands Skilled and careful use of the balloon occlusion technique should not expose the patient to any more risk than ordinary catheter angiography

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REFERENCES

ABRAMS H L. The response of neoplastic renal vessels to epinephrine in man *Radiology* [illegible] (1964) 217

ADAMS D OLIN T and REDMAN H Catheterization of arteries in the rabbit *Radiology* [illegible] (19[illegible]) 531

ALMEN T A steering device for selective angiography and some vascular and enzymatic reactions observed in its clinical application Acta radiol (1 [illegible]) Suppl No 260

BOIJSEN F and REDMAN H Effect of bradykinin on celiac and superior mesenteric angiography J invest Radiol 1 (1966) 422

CHENDEROVITCH J et CAROLI J La microangioradiographie du foie et de la rate Rev [illegible] Hépat 6 (19[illegible]) [illegible]07

GINSBURG M and GRAYSON J Factors controlling liver blood flow in the rat J Physiol 123 (19[illegible]) 574

HAVERLING M Renal phlebography An experimental study in the pig Acta radiol (1[illegible]) Suppl No 2[illegible]1

JACOBSSON B Use of Dextran in prophylaxis against thromboembolic complications in arterial catheterization Acta chir scand (1968) Suppl. No 387 p 103

KESSLER L. A and WHOLEY M H Internal carotid occlusion for treatment of intracranial aneurysms A new percutaneous technique Radiology 9[illegible] (1970) [illegible]81

MAC DONALD D A and POTTER J M The distribution of blood to the brain J Physiol 114 (19[illegible]1) 3[illegible]6

NAKAMURA T NAKAMURA S ONODERA A AIKAWA T and IIDA H. Hepatic venography in hepatic tumours Tohoku J exp Med 99 (196[illegible]) 281

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FROM THE DEPARTMENTS OF SURGERY (DIRECTOR F KOCH) AND DIAGNOSTIC RADIOLOGY (DIRECTOR R SUNDGREN), CENTRALLASARETTET, KRISTIANSTAD, AND THE DEPARTMENT OF CYTODIAGNOSTICS (DIRECTOR N STORMBY), UNIVERSITY HOSPITAL LUND SWEDEN

SELECTIVE ANGIOGRAPHY IN FINE NEEDLE ASPIRATION CYTODIAGNOSIS OF GASTRIC AND PANCREATIC TUMOURS

by

J OSCARSON N STORMBY and R SUNDGREN

Selective angiography has proved of great value in facilitating the examination of abdominal vessels and increasing the diagnostic accuracy Its superiority over non selective methods is incontestable in morphologic and topographic investigations of organ vasculature (BOIJSEN 1966 SUNDGREN 1969, 1970, REUTER *et coll* 1970) The combination of aspiration biopsy considerably improves the results This form of biopsy employing a fine needle (OD 0 6 to 0 8 mm is a standard examination procedure in many hospitals in Sweden when palpable masses are present e g in the breasts, liver lymph nodes, prostate salivary glands Roentgenography with fluoroscopy and TV amplification as a guide to fine needle aspiration has been reported as giving good results in the diagnosis of pulmonary tumours by DAHLGREN & NORDENSTROM (1966 The difficulty in demonstrating changes in the stomach and especially in the pancreas by this method has until now impeded its application in these areas It has however created opportunities for improved accuracy and reliability in the preoperative morphologic diagnosis of lesions by guiding the puncture needle into deep-seated organs.

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— — WATANABE M, SUZUKI T, TOKITA K, KIMURA T, SATO T and KANEKO T Studies on cirrhosis of the liver VII Hepatic venography in clinical cases Tohoku J exp Med 69 (1959), 275

NORDENSTROM B Balloon catheters for percutaneous insertion into the vascular system Acta radiol 57 (1962) 411

NORHAGEN Å Selective angiography of the hepatic veins Experimental investigations of basal circulatory dynamics Acta radiol (1963) Suppl No 221

OLIN T Studies in angiographic technique Thesis Håkan Ohlssons Boktryckeri Lund 1963

— and REUTER S A pharmacoangiographic method for improving nephrophlebography Radiology 85 (1965) 1036

REIN H Vasomotorische Schutzreflexe aus dem Stromgebiet der Arteria hepatica Pflügers Arch ges Physiol 246 (1943) 866

PORCH JR P P, CHAMBERLAIN N O and EDWARDS W H The effects of temporary renal vascular occlusions in dogs Surg Forum 10 (1960) 892

SANCETTA S M Dynamic and neurogenic factors determining the hepatic arterial flow after portal occlusion Circulat Res 1 (1953) 414

SCHWIEGK H Physiologie und funktionelle Pathologie der Leberdurchblutung Dtsch Z Verdau u Stoffwechselkr (1953) Sonderband XV

SENEVIRATNE R D Physiological and pathological responses in the blood vessels of the liver J Physiol 108 (1949) 77

TAKARO T, DOW J A and KISCHEV S Selective occlusive renal phlebography in man Radiology 94 (1970) 589

THALHEIMER M et GILLOT C La cavographie segmentaire Etude expérimentale de l'opacification des veines rénales et des veines sus hépatiques Coll int Chir 38 (1962) 561

VIRTANEN G Personal communication (1970)

WHOLEY M H, STOCKDALE R and HOVE T K A percutaneous balloon catheter for immediate control of hemorrhage Radiology 95 (1970) 65

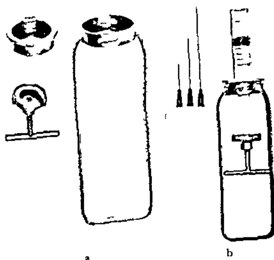


Fig 2 a) Adapter for disposable plastic syringes according to Stormby b) The aspiration instrument assembled The needles depicted are used for subcutaneous growths and lymph nodes (Size 1 5)

was allowed to remain in the vessel after this standardized angiographic examination was concluded

A modified aspiration instrument (Fig 2) developed by STORMBY, was used for the biopsies The modification is in principle an inexpensive adapter for a disposable plastic syringe built to FRANZEN s original construction, that makes it possible to perform powerful aspiration movements with one hand By employing disposable syringes multiple aspirations may be made without dependence on a large supply of glass instruments The whole is ready for use once the adapter is assembled, a process taking only a few seconds The aspiration needles have an OD of between 0 6 and 0 8 mm and vary from 80 to 150 mm in length The longer aspiration needles are necessary in adipose patients if the dorsal wall of the stomach or the pancreas is to be reached

Care in executing the aspiration and smear techniques is imperative if an optimal diagnostic result is to be obtained When it is considered that the aspiration needle has been well inserted into solid tissue it is moved vigorously back and forth in the puncture channel Too prolonged aspiration usually yields an undesirable mixture of blood in the injector small aspirates — hardly of more material than fills the lumen of the needle — are often quite sufficient Another important detail is that careful attention must be paid that too small amounts of aspirate are not apportioned to a large number of slides, the result will be thin smears with distorted cells and a superfluity of artefacts Two to 6 smear preparations will generally suffice The cytologic investigation was carried out consistently with smears that had been fixed in 95 % ethanol and then stained with

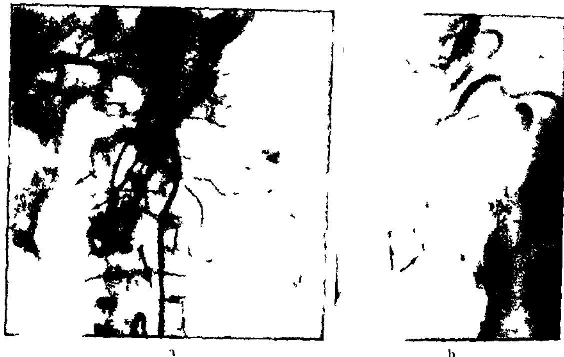


Fig. 1. Woman aged 56. Carcinoma of the ventricular canal. Selective angiography of left gastric artery. Involvement of the ventral and dorsal branches to the canal (→). The anterior and posterior arterial arches along the lesser curvature distal to the angular notch are likewise affected; this means that the neoplasm has spread under the mucosa out into the lesser omentum (←).

Methods. The patients were prepared in the same way as for regular angiography of the abdominal organs. The stomach was distended with gas, which facilitates catheterization, particularly of the left gastric artery, and also provides increased possibilities of the topographic discrimination of the various parts and an exact delimitation of any vascular changes that may have occurred (SUNDGREN 1970). In addition, the vessels in the gastric wall are separated so that the reliability of the topographic and morphologic evaluation of the pancreas increases. The combined examination was preceded by a routine roentgen examination of the epigastrium with the stomach distended, a marker placed along the midline of the abdominal wall indicated the position of the stomach and pancreas.

The examination was carried out in the a.p. projection with the patient supine (Fig. 1 a) as well as in the right lateral position (Fig. 1 b), and in the lateral projection with the patient lateral. The angiographic examination included one or more of the vessels of the abdominal organs, e.g. the left gastric artery, celiac artery or superior mesenteric artery, depending on which organ or part of organ was selected for biopsy and the above mentioned three projections. The catheter

Table I

Gastric diseases A conventional roentgen examination was performed initially The histologic diagnosis was obtained either at operation or autopsy

Case No	Sex	Age	Angiography	Cytologic diagnosis	Histologic diagnosis	Remarks
1	Female	81	Carcinoma	Mucus-forming adenocarcinoma	Poorly differentiated adenocarcinoma	
2	Male	66	Carcinoma	Carcinoma	Poorly differentiated adenocarcinoma	
3	Female	86	Carcinoma	Poorly differentiated adenocarcinoma		At operation large inoperable carcinoma gastric metastases
4	Female	61	Vessel concentration	Benign		
5	Male	70	Carcinoma	Carcinoma	Poorly differentiated adenocarcinoma	
6	Female	62	Carcinoma	Possible malignancy	Poorly differentiated adenocarcinoma	
7	Male	73	Carcinoma	Benign cells	Inflammatory atypical epithelium	
8	Female	47	Linitis plastica	Necrotic material no malignant cells	Poorly differentiated adenocarcinoma	
9	Female	50	*Leiomyoma neurinoma*	*Benign mesenchymal cells leiomyoma*	Leiomyoma	Tumour situated submucosally
10	Male	71	Carcinoma	Moderately differentiated adenocarcinoma		
11	Male	74	Probable carcinoma	Benign		Lesion healed at roentgen control
12	Male	45	*Benign*	*Insufficient material*		
13	Female	65	Carcinoma	Intermediately differentiated adenocarcinoma		

and duodenum The clinical part of the investigation included routine laboratory tests of the blood urine and gallbladder and liver as well as electrophoresis. Selective angiography of the left gastric artery was performed in 12 + 1 patients

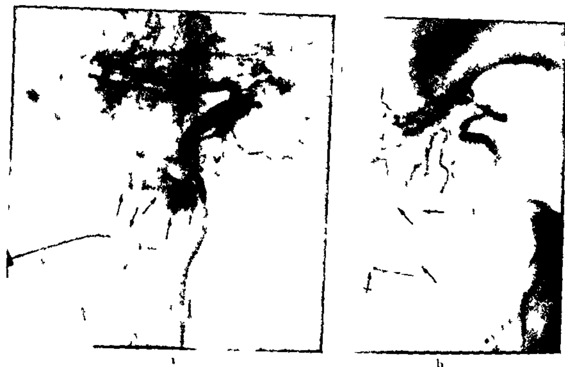


Fig 3 Pathologic changes localized during fluoroscopy by means of repeated injections of contrast medium into the left gastric artery (→) while percutaneous fine needle biopsy is performed a) Ap and b) lateral views indicate the position of the needle (↔) during the injection of contrast medium

hematoxylin eosin Air drying followed by Giemsa staining is also possible, although perhaps less suitable for this type of cell material, which may be commingled with large amounts of detritus or gastric contents or both Papanicolaou staining is optional

The percutaneous biopsy was performed with the patient in the right lateral position and with the investigator sitting in front The site was determined by reference to the previously mentioned marker on the abdomen After local anesthesia, the aspiration needle was passed through the abdominal wall towards the affected organ area simultaneously as the vascular topographic site of the pathologic process was demonstrated angiographically on the screen of the monitor by short, repeated manual injections of contrast medium through the selectively inserted catheter (Fig 3) Radiation protection for the investigator may be satisfactorily maintained by careful limitation of the area of investigation and the choice of a long aspiration needle

Material This comprised 20 men and women aged between 45 and 86 years Thirteen were investigated for gastric changes and 7 for abnormalities of the pancreas All were examined before the angiographic examination and percutaneous biopsy with a conventional barium meal examination of the stomach

Table 1

Gastric diseases A conventional roentgen examination was performed initially The histologic diagnosis was obtained either at operation or autopsy

Case No	Sex	Age	Angiography	Cytologic diagnosis	Histologic diagnosis	Remarks
1	Female	81	Carcinoma	Mucus-forming adenocarcinoma	Poorly differentiated adenocarcinoma	
2	Male	66	Carcinoma	Carcinoma	Poorly differentiated adenocarcinoma	
3	Female	86	Carcinoma	Poorly differentiated adenocarcinoma		At operation large inoperable carcinoma gastric metastases
4	Female	61	Vessel concentration	Benign		
5	Male	70	Carcinoma	Carcinoma	Poorly differentiated adenocarcinoma	
6	Female	62	Carcinoma	Possible malignancy	Poorly differentiated adenocarcinoma	
7	Male	73	Carcinoma	Benign cells	Inflammatory atypical epithelium	
8	Female	47	Linitis plastica	Necrotic material no malignant cell	Poorly differentiated adenocarcinoma	
9	Female	50	Leiomyoma neurinoma	Benign mesenchymal cell leiomyoma	Leiomyoma	Tumour situated submucosally
10	Male	71	Carcinoma	Moderately differentiated adenocarcinoma		
11	Male	74	Probable carcinoma	Benign		Lesion healed at roentgen control
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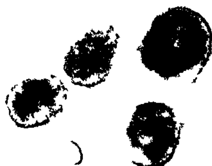


Fig 1 Cells (adenocarcinoma) from stomach Htx eosin ×1 000



Fig 2 Material aspirated from submucous tumour (leiomyoma) of stomach wall Htx eosin ×1 000

(the first group of gastric the second group of pancreatic patients) Angiography of other abdominal vessels was also the rule in these 13 patients Selective angiography of the superior mesenteric artery was carried out in 2 + 2 patients of the celiac artery in 8 + 5 of the common hepatic artery in 2 + 1 and of the posterior gastric artery in 1 + 0 patients

Results

Group I (gastric cases Table 1) The number of patients examined was 14, in 7 of whom the final histologic diagnosis was gastric carcinoma, in 5 of these 7 patients (all with adenocarcinoma) the diagnosis was conclusive One patient received a cytologic diagnosis of possible malignancy In another leucocytes and necrotic material were obtained at biopsy but no malignant cells in spite of the fact that the selective angiographic examination of the left gastric artery revealed malignancy (so called 'linitis plastica'), the aspiration

Table 2

Pancreatic diseases. A conventional roentgen examination was performed initially. The histologic diagnosis was obtained either at operation or autopsy.

Case No	Sex	Age	Angiography	Cytologic diagnosis	Histologic diagnosis	Remarks
1	Female	77	No pathology vessels in head of pancreas enlarged	Strong suggestion of carcinoma	Adenocarcinoma pancreatitis	
2	Male	76	Pancreatic cyst	Cystic fluid		Operation small gastric tumour diagnosis by roentgenography and gastroscopy
3	Female	46	Carcinoma	Scanty material no signs of malignancy	Chronic pancreatitis	
4	Male	78	Expansive process in head of pancreas	Normal glandular epithelium from pancreas	Lipoma	The lipoma bulged against the stomach
5	Male	72	Carcinoma	Adenocarcinoma	Adenocarcinoma pancreatitis	
6	Male	67	Normal	Insufficient material		Clinically relapsing acute pancreatitis in alcoholic
7	Male	66	Infiltrating process within tail of pancreas	Cells as in chronic pancreatitis		Exploratory laparotomy within normal limits clinically subchronic pancreatitis

needle was observed during fluoroscopy to make an indentation in the gastric wall

Four patients with non neoplastic gastric disease are included in the material 2 of these had a roentgenographically verified gastric ulcer Cytologically benign epithelial cells were confirmed with inflammatory changes in agreement



Fig 4 Cells (adenocarcinoma) from stomach Htx eosin ×1 000

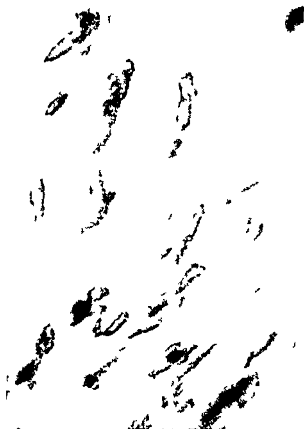


Fig 5 Material aspirated from submucous tumour (leiomyoma) of stomach wall Htx eosin ×1 000

(the first group of gastric, the second group of pancreatic patients) Angiography of other abdominal vessels was also the rule in these 13 patients Selective angiography of the superior mesenteric artery was carried out in 2 + 2 patients, of the celiac artery in 8 + 5, of the common hepatic artery in 2 + 1 and of the posterior gastric artery in 1 + 0 patients

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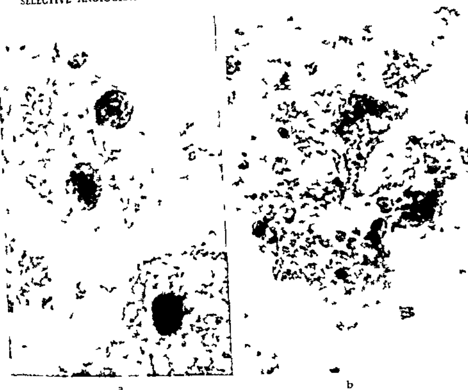


Fig 6 a) Lipophages from case of pancreatitis Htx eosin × 1 000 b) Calcified debris from the same case Htx eosin × 440

An impression in the ventricular canal was evident in the conventional roentgen examination of the stomach and duodenum in Case 4 The angiographic examination demonstrated an expansive process in the region but no vessels were involved by tumour Fine needle biopsy revealed normal pancreatic cells (Fig 7) During the explorative laparotomy a lipoma was discovered in the anterior abdominal wall bulging against the stomach and producing an impression The pancreas and stomach appeared to be completely normal

The roentgen examination demonstrated a cyst within the body of the pancreas in Case 2 A proteinogenous precipitate corresponding to the cystic fluid and containing chiefly inflammatory cells constituted the fine needle biopsy sample The patient suffered from persistent epigastric pain for which reason gastroscopy was subsequently performed and a tissue sample collected Early malignancy was disclosed in the pyloric canal and the patient underwent

with the cell appearances at the edge of an ulcer A Billroth II operation was performed in one of the patients and a gastric ulcer confirmed The other patient was treated conservatively and the lesion healed A rounded, 5 cm tumour was observed in the dorsal part of the fornix in a third patient This was supplied entirely by the posterior gastric artery, which arose from the celiac artery 0 5 cm distal to the origin of the left gastric artery, of nearly the same calibre, 3 to 4 mm, it was possible to examine both arteries The tumour was a highly vascularized leiomyoma The drainage was by a large vein that ran parallel to the artery into the portal vein The region involved was connected with the adjacent parts of the stomach and the left gastric artery by the customary interregional anastomoses of ordinary calibre Fluoroscopy revealed that the tip of the needle was penetrating and moving the tumour Mostly normal epithelial cells as well as smaller formations of mesenchymal cell elements of benign appearance were recovered from the gastric mucosa The findings again suggested a leiomyoma (Fig 5) This was confirmed by gastroscopy, operation and finally histology

An earlier partial gastrectomy (Billroth I) was confirmed in the fourth benign case Selective angiography of the left gastric, splenic and celiac arteries demonstrated an abundance of vessels in the non resected part Fine needle biopsy of several areas of the stomach yielded only normal cells in the cytologic investigation In this instance, the examination was undertaken because the patient had complained of epigastric discomfort which subsequently gradually subsided under medical treatment

Group II (pancreatic cases Table 2) Seven patients were examined, 2 of these jaundiced and with carcinoma of the pancreas, indicated by the fine needle biopsy Both patients were inoperable and the cytologic diagnosis was verified macro- and microscopically at autopsy One of the 5 patients with non neoplastic pancreatic disease (Case 3, Table 2) had clinical evidence of chronic pancreatitis Although the biopsy yielded a scanty amount of material, there was no evidence of malignancy This patient subsequently underwent choledochoduodenostomy, resection of the tail of the pancreas and pancreaticojejunostomy The diagnosis of chronic pancreatitis was confirmed

Case 7 had clinical evidence of chronic, relapsing pancreatitis Exploratory laparotomy was performed and the pancreas was found to be somewhat enlarged and irregular although not indurated Cholangiography was carried out and a normal flow to the intestine was confirmed A further angiographic examination of the pancreas was undertaken and in conjunction with this fine needle biopsy gave the cytologically most probable diagnosis of chronic pancreatitis (Fig 6) This patient has since been observed for a year and is clinically improved, with only insignificant reduction in pancreatic function

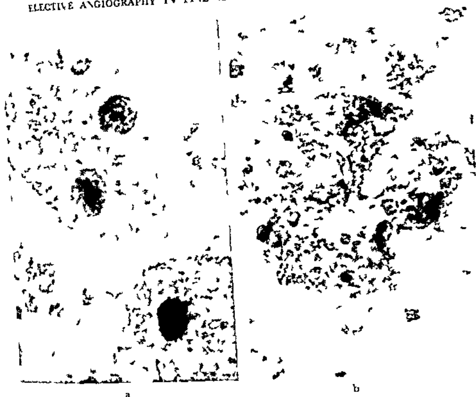


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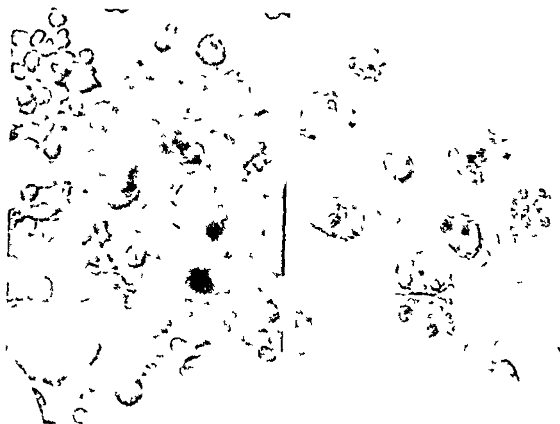


Fig 7 Normal acinar cells from pancreas Htx eosin × 1 000

Fig 8 Adenocarcinoma of pancreas Htx eosin × 1 000

gastric resection, the pancreas was palpable and within normal limits A review of the roentgenograms and slide preparations has suggested that the pancreatic cyst and carcinoma of the stomach probably existed together

Case 6 was clinically one of acute recurring pancreatitis in an alcoholic Roentgen examination of the stomach and duodenum and cholangiography as well as angiography were within normal limits Needle biopsy yielded insufficient diagnostic material The patient, observed now for about a year, has had further mild attacks of pancreatitis but between these has been free of discomfort and has had full pancreatic function

The fine needle biopsy was followed the next day by conventional roentgenography of the abdomen which was within normal limits in all instances No clinical complications have been recorded The biopsy in 3 patients was performed the day preceding the laparotomy without the surgeon finding anything unusual within the puncture area In conjunction with the pancreatic biopsies, urinary amylase has also been checked for a few days after the biopsy without

increased values being recorded. The patients have not experienced the fine needle puncture as painful or unpleasant.

Discussion

Fine needle biopsy for cytodiagnostics has up to the present time chiefly been employed with palpable tumours and other tissue changes or in lesions that can be demonstrated by fluoroscopy, e.g. pulmonary tumours. On the other hand angiography and fine needle aspiration in combination have not been reported previously. This combined technique has shown promise as regards changes in the stomach; accordingly a definitive cytologic diagnosis of adenocarcinoma could be made in 5 out of 7 patients, while in one additional patient malignancy was considered probable. The case not yielding material for a cytologic diagnosis was one of linitis plastica, i.e. scirrhous diffuse wall infiltrating malignancy.

These latter tumours may, as is well known from mammary carcinoma, offer considerable difficulty in cytologic aspiration biopsy owing to the scanty epithelial components which mostly grow in small cords in an extremely profuse connective tissue. Since practically only epithelial cells are recovered in fine needle aspiration while connective tissue, e.g. in the guise of tumour stroma, is seldom observed in the smear preparation, it is obvious that the copiously stromatized scirrhous tumours provide insufficient biopsy material. This is also true in mesenchymal tumours such as neurinomas or myomas. With a tangential approach to the stomach wall and a sharp needle the possibilities of recovering representative material in scirrhous carcinoma are somewhat enhanced. As regards mesenchymal tumours the material contains a case of a leiomyoma in which small fragments of the neoplastic tissue yielded sufficient diagnostic information. A different design of needle tip may perhaps further improve the recovery of tissue, since these tumours lie submucosally; biopsy samples cannot usually be obtained with the gastroscope.

The technique of fine needle aspiration is simple and free of complications apart from the difficulty in obtaining material from certain kinds of tumours. It is important that the negative pressure be maintained when the needle is in the gastric lumen to preclude excessive intermixing of mucus and detritus. Great care must be devoted to smearing the preparation and fixing, which must ensue before the smear has dried. Since neoplastic and other changes generally lie relatively superficially they may of course be revealed at angiography. Changes as small as 3 cm have however been reached with the aspiration needle.

The few cases of pancreatic tumours aspirated by the method naturally permit no definite conclusion regarding its application. Operation in a material of fine needle aspirations of pancreatic lesions (ARNESJO et coll. 1972), have however indicated that cytologic and histologic diagnostics are on a parity. Moreover, it is clear that the risk of complications is minimal. No complications were recorded in the present investigation, which is remarkable when consideration is paid to the fact that the stomach and intestines had to be passed in conjunction with the percutaneous puncture. Injury to the pancreas has not been evident in those patients who have been subjected to operation. It may be expected that with additional experience and further refinement of the technique possibilities will exist for recovery of diagnostic cytologic material from comparatively small tumours of the stomach and pancreas.

SUMMARY

Selective rather than non selective angiography with TV amplification makes it possible to perform aspiration biopsies with great precision from relatively small localized pathologic processes within organs. This examination has been performed in 20 patients, 13 with possible gastric and 7 patients with possible pancreatic changes. The procedure is free of complications and constitutes an important adjunct in the diagnosis of conditions affecting the stomach and pancreas.

ZUSAMMENFASSUNG

Selektive eher als nicht selektive Angiographie mit Fernseh-Vergrösserung ermöglicht es Aspirationsbiopsien von relativ kleinen lokalisierten pathologischen Prozessen innerhalb von Organen mit grosser Genauigkeit auszuführen. Diese Untersuchung wurde an 20 Patienten ausgeführt, bei 13 mit möglichen Veränderungen des Magens und bei 7 des Pankreas. Dieses Verfahren ist komplikationsfrei und bildet ein wesentliches Hilfsmittel bei der Diagnose von Bedingungen, unter denen der Magen oder das Pankreas betroffen sind.

RÉSUMÉ

Mieux que l'angiographie non sélective, l'angiographie sélective avec radioscopie télévisée permet de faire des aspirations biopsies de grande précision sur des processus pathologiques relativement petits et localisés dans des organes. Cet examen a été pratiqué chez 20 malades dont 13 avaient probablement des lésions gastriques et 7 des lésions pancréatiques. Cette méthode est dépourvue de complications et constitue une aide importante au diagnostic d'affections gastriques et pancréatiques.

REFERENCES

ARNESJO B, STORMBY N and AKERMAN M Cytodiagnosis of pancreatic lesions by means of fine needle biopsy during operation Acta chir scand 138 (1972) 363

BOIJSEN E Viszerale Angiographie (Leber Magen Darm) *In* Angiographie Methoden Indikation Ergebnisse p 85 Herau gegeben von K E Loose Thieme Verlag Stuttgart 1966

DAHLGREN S and NORDENSTROM B Transthoracic needle biopsy Almqvist & Wiksell Stockholm 1966

FRANZEN S GIERTZ G and ZAJICEK J Cytological diagnosis of prostatic tumours by transrectal aspiration biopsy A preliminary report Brit J Urol 32 (1960) 193

LUNDERQUIST A Angiography in carcinoma of the pancreas Acta radiol (1965) Suppl No 236

REUTER S R REDMAN H C MILLER W J and HOSKINS P A Gastric angiography Radiology 94 (1970) 271

SUNDGREN R Selective angiography of the left gastric artery Method anatomy Paper presented at the meeting of the Swedish Society for Radiology Lund 1969

— Selective angiography of the left gastric artery Acta radiol (1970) Suppl No 299

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COMPLICATIONS IN TRANSLUMBAR AORTOGRAPHY

A comparison of direct needle puncture and aortic catheterisation

by

SVEN DORPH and KIRSTEN FOLKE

The technique described by SELDINGER (1953) for transfemoral aortic catheterisation is now generally the method of choice for aortography Narrowing or occlusion of the iliac arteries associated with vascular disease of the pelvis and lower extremities may however sometimes make the transfemoral approach difficult hazardous or even impossible

Translumbar puncture of the aorta appears sometimes to be used as a routine in arteriosclerosis it is also employed when the transfemoral route is not possible to use A modification of translumbar aortography with a teflon catheter needle combination was introduced by AMPLATZ (1963) The direct puncture technique (with injection of contrast medium through a metal needle) was used in our department until 1966 when it was superseded by the teflon catheter method This communication consists of an analysis of the complications of the total number of translumbar aortographies performed up to 1971

Material and Methods The translumbar technique for aortography was chosen only when no pulse could be felt in the femoral arteries or when transfemoral catheterisation had failed The method was also used in a few cases of aneurysm of the lower part of the aorta or iliac arteries

The material consisted of 420 examinations in 364 cases, the indications for which were the following Arteriosclerosis of the lower extremities (400), hyper

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Table 1

Age and sex distribution (420 examinations)

	No of examinations	Age (years)	
		Range	Mean
Males	313	33–78	58 8
Females	107	14–74	56 4

tension — stenosis of the renal artery (6), hypertension — coarctation of the aorta (1) aneurysm of the femoral artery (3), aneurysm of the abdominal aorta (2) renal tumour (2) pancreatic tumour (1) embolism of the abdominal aorta (?) occlusion of the femoral artery (1) Raynaud s disease (1) and coarctation of the abdominal aorta and the common iliac arteries (1) A total of 175 examinations was performed with the direct needle puncture technique under general anaesthesia without fluoroscopy The aorta was perforated just below the renal arteries and 40 ml × 2 Urografin 76 % or Conray 400 mg I/ml injected manually for the demonstration of the aorta and the arteries of the pelvis and lower extremities The remaining 245 cases were examined under local anaesthesia with the teflon catheter needle The aorta was perforated at the level of Th12 under fluoroscopic control and a guide wire was introduced The needle having been withdrawn the 18 gauge 4 inch teflon catheter (Becton Dickinson and Co Drogheda Ireland) was advanced into the lumen of the thoracic aorta (AMPLATZ) The correct position of the catheter was controlled by a small test injection A Gidlund injector and 40 ml × 2 of Urografin 76 % or Conray 400 mg I/ml were used

Bleeding and coagulation times and thrombocyte count were controlled before each examination so as to exclude cases with a hemorrhagic diathesis A prothrombin proconvertin time of at least 50 per cent was also required in cases treated with anticoagulants The age and sex distribution which were equal for the two groups are given in Table 1

Results

Aortic puncture with the teflon catheter technique failed in 7 cases (3 per cent) and in a further 7 examinations (3 per cent) the guide wire could not be advanced into the lumen of the aorta With the direct needle method aortic puncture failed in 17 cases (10 per cent) and in another 10 cases (6 per cent) the vessels were not demonstrated because of intramural or perivascular introduction of the contrast medium

Table 2

Perivascular and intramural aortic injection of contrast medium

	Perivascular injection (number of examinations)		Intramural injection (number of examinations)		Percentage of cases with perivascular or intramural injection	
	Slight	Marked	Slight	Marked	Slight	Marked
Direct needle puncture	5	7	6	5	6.3	6.8
Teflon catheter technique	4	0	4	0	3.3	0

The complications of the total material were as follows: Retroperitoneal abscess (1), perivascular or intramural aortic injection (31), pain following procedure (26), raised temperature following procedure (24), haematoma, observed during operation (3), accidental puncture of spinal canal (1), accidental injection into renal artery (1), reaction to contrast medium (1), anaesthetic complications (2).

Complication 1. Fatal outcome of the examination occurred in one case.

Male aged 62 with an occlusive vascular condition of the lower extremities was examined with the teflon catheter technique. The aorta was perforated after several attempts and the examination was then carried out without immediate complications. During the following days the patients developed peritoneal signs. Explorative laparotomy at the fifth day revealed a large retroperitoneal and subhepatic abscess and evidence of massive pancreatitis; no obvious perforation of the bowel. The postoperative course was complicated by renal failure, and the patient died in uraemia at three weeks.

Complication 2. Intramural and perivascular injection of a greater part of the medium occurred only in the group examined with direct needle puncture (Table 2); with the teflon catheter, a small amount (1 to 2 ml) of medium was deposited outside the aortic lumen in a few cases and only during a test injection. Except for a higher frequency of lumbar pain following the procedure (20 as against 5 per cent for the rest of the material), no immediate symptoms were recorded.

Perivascular injection of Conray failed to cause any immediate reactions in one case (Fig. 1a). A further and successful examination four days later disclosed extensive arteriosclerosis. Narrowing of the distal part of the aorta and slight displacement of the left kidney were also evident (Fig. 1b). Operation ten days after the first examination disclosed marked infiltrative changes in the perivascular area of the abdominal aorta. Microscopy revealed chronic inflammation.



Fig 1 Translumbar aortography (direct needle puncture) a) Free pulsating flow was observed but the needle pos t on was not checked and the contrast medium was deposited perivascularly b) Four days later Extensive arteriosclerosis in distal part of abdominal aorta No visible vascular changes at the site of the previous perivascular injection Slight displacement of the left kidney has occurred (→)

Complications 3 and 4 Pain persisting after termination of the aortographic procedure characteristically in the lumbar region with belt shaped extension to the abdomen and fever (never exceeding 39 C) occurred with the same frequency in the two groups These symptoms never lasted for more than three days

Complication 5 The site of puncture could be examined directly during operation (thrombectomy bypass left sided sympathectomy) within ten days after the examination in 30 cases retroperitoneal hematomas were evident in 3 of these cases

Hemoglobin values were available from blood specimens taken between ten to one days before and two to ten days after the examination in 148 cases The values were compared to determine the incidence and size of the hematomas after aortic puncture Cases in which operation or blood transfusion were performed in relation to these time intervals were excluded (Fig 2) The average fall in hemoglobin for the whole material was 6 1 per cent the age or the examination technique having no influence in 15 cases with pain or fever the average fall was however 10 5 per cent and in 8 cases of hypertension the figure was 9 4 per cent Blood transfusion or surgical hemostasis was never required

Complication 6 The spinal canal in one case was accidentally punctured with the teflon catheter needle probably above the conus medullaris. The needle was withdrawn and no complications developed

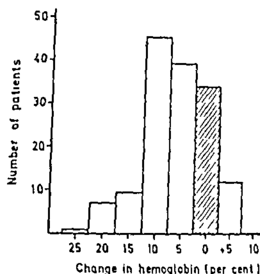


Fig. 2. Change in hemoglobin values after translumbar aortography (percentage of values before examination) in *118* cases.

Complication 7. A total of 10 + 10 ml of Urografin was injected into the left renal artery without demonstrable sequelae in a case of direct needle puncture.

Complication 8. Only one case had signs of hypersensitivity with transient urticaria.

Complication 9. Two cases had a fall in blood pressure and tachycardia during general anaesthesia before the puncture. The examination was interrupted and recovery ensued. Local anaesthesia caused no complications.

Discussion

The fatality described was probably caused by perforation of the pancreas or the bowel in combination with a periaortic hematoma. Such a serious complication will be avoided if every precaution be taken to ensure that the tip of the needle touches the vertebral body before it is directed forwards to the aorta. This rule was not observed during the several first unsuccessful punctures in the present case. Accidental puncture of the spinal canal also seems to be due to an avoidable error in technique.

A certain number of intramural and perivascular injections seem inevitable with the technique described for direct needle puncture. A frequency of about 10 per cent is freely mentioned (McAfee 1957, Boblitt et coll. 1959). Boblitt et coll. described three deaths in 12 cases of intramural injection from a dissecting aneurysm surrounding the renal arteries. Spinal lesions may also result from dissection of the aortic wall although their origin is often difficult to evaluate. A similar frequency of perivascular and intramural complications (13 per cent) was recorded in the series of direct needle puncture. Fluoroscopy or a test

injection would probably have reduced this frequency somewhat, but a considerable risk of displacement of the needle tip during the procedure would still have remained LINDGREN (1953) has described a method to ensure a stable intraluminal position of the needle tip The present authors have no experience of this technique which would probably further have contributed to the prevention of false injections This potentially dangerous complication is almost completely avoided by the teflon catheter method and fluoroscopy

Regarding other complications no difference in frequency appears to exist in the two series The fall in hemoglobin after the examinations was also about the same This seems to indicate that the hematoma after a translumbar puncture often represents several hundred ml of blood (10 per cent average fall in two thirds of cases)

The reason for the higher frequency of unsuccessful aortic punctures in the group examined with the direct needle technique is probably that a lower site of puncture (below the renal arteries) was employed with the possibility of perforating a totally occluded aorta This was sometimes confirmed by transaxillary aortography

Besides avoiding intramural and perivascular injections the teflon catheter technique provides several other advantages (1) Injection into the thoracic part of the aorta provides information on the entire abdominal aorta and its branches (2) The patient may move fairly freely without any danger of the aortic wall being perforated (3) The catheter allows the use of a power injector (4) The examination may be performed under local anaesthesia This is hardly to be recommended in direct needle puncture

Some radiologists consider translumbar aortography simple and safe (BEALL et coll 1963 KINCAID 1958) The present work as well as several others (BOBLITT et coll 1959 MCAFEE 1957 GAYLIS & LAWS 1956) indicate that a certain risk cannot be ignored The fact that the procedure has to be carried out with the patient prone may prove to be a problem in those seriously ill Transfemoral as well as axillary or brachial catheterisation may however also be hazardous or even impossible in occlusive vascular disease The translumbar route then becomes an important alternative and the introduction of the teflon catheter technique must be regarded as a contribution to the improvement of quality and reduction in the risks of this method of examination

SUMMARY

The complications in a series of 420 translumbar aortographies have been analysed A total of 175 examinations were performed by the direct percutaneous needle puncture method and in the remaining 245 cases the aorta was catheterized with the teflon catheter

technique of AMPLATZ. The latter method has reduced the risks of intramural and periaortic injection of contrast medium to a negligible figure. It has also provided a higher frequency of successful examinations.

ZUSAMMENFASSUNG

Die Komplikationen bei einer Serie von 420 translumbaren Aortographien wurden analysiert. Insgesamt 175 Untersuchungen wurden mit direkter perkutaner Nadel-Punktions-Methode durchgeführt, und in den restlichen 245 Fällen wurde die Aorta mit der Teflon-Katheter-Technik von AMPLATZ katheterisiert. Letztere Methode hat das Risiko intramuraler oder periaortaler Injektion von Kontrastmittel auf eine zu vernachlässigende Grösse vermindert. Diese ergab auch eine höhere Frequenz erfolgreicher Untersuchungen.

RÉSUMÉ

Les auteurs ont étudié les complications d'une série de 420 aortographies translombaires. Cent soixante-quinze examens ont été faits par la méthode de ponction percutanée directe à l'aiguille et dans les 245 autres cas l'aorte a été cathétérisée par la technique de cathéter en teflon d'AMPLATZ. Cette dernière méthode a réduit à un chiffre négligeable les dangers d'injection intramurale et périaortique de moyen de contraste. Elle a aussi donné une fréquence plus grande d'examens réussis.

REFERENCES

AMPLATZ, K.: Translumbar catheterization of the abdominal aorta. Radiology 81 (1963), 927.

BEALL, A. C., HENLY, W. S., MORRIS, G. C., CRAWFORD, E. S., COOLEY, D. A. and DEBAKEY, M. E.: Translumbar aortography. A simple safe technic. Ann. Surg. 157 (1963), 882.

BOBLITT, D. E., FIGLEY, M. M. and WOLFMAN, E. F.: Roentgen signs of contrast material dissection of aortic wall in direct aortography. Amer. J. Roentgenol. 81 (1959), 826.

GAYLIS, H. and LAWS, J. W.: Dissection of aorta as a complication of translumbar aortography. Brit. med. J. 1956, II, p. 1141.

HAUT, G. and AMPLATZ, K.: Complication rates of transfemoral and transaortic catheterization. Surgery 63 (1968), 594.

KINCAID, O. W.: Translumbar aortography. Sth. med. J. 51 (1958), 455.

LINDGREN, E.: Technique of abdominal aortography. Acta radiol. 39 (1953), 205.

McAFEE, J. G.: A survey of complications of abdominal aortography. Radiology 68 (1957), 825.

SELDINGER, S. I.: Catheter replacement of the needle in percutaneous arteriography. A new technique. Acta radiol. 39 (1953), 368.

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RAPID CHANGES IN THE VOLUME OF THE LATERAL VENTRICLES AT ENCEPHALOGRAPHY

by

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The perusal of a limited and randomly selected material of encephalographies in children indicated that the width of the anterior parts of the lateral ventricles were sometimes larger before than after the temporal horn filling procedure This was particularly evident in cases where by chance the a.p projections obtained after the manoeuvre were identical with those taken before the comparison being made both by superimposition and measurement The maximum and average degree in variation of volume and the frequency in which they occurred was investigated

The encephalographic procedure The encephalographic examinations were performed by the conventional standardized method with fractionated exchange of cerebrospinal fluid and gas (ROBERTSON 1946 LINDGREN 1949) The examination of the posterior fossa and posterior parts of the ventricles was carried out in the sitting and ventrally tilted positions respectively then with the patient recumbent three p a views at various angles and one lateral view were usually obtained If the temporal horns were not sufficiently filled with gas a separate filling manoeuvre was carried out either in the conventional way by dorsiflexing and turning the head or by a forward somersault

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technique of AMPLATZ The latter method has reduced the risks of intramural and periaortic injection of contrast medium to a negligible figure It has also provided a higher frequency of successful examinations

ZUSAMMENFASSUNG

Die Komplikationen bei einer Serie von 420 translumbaren Aortographien wurden analysiert Insgesamt 175 Untersuchungen wurden mit direkter perkutaner Nadel Punktions Methode durchgeführt und in den restlichen 245 Fällen wurde die Aorta mit der Teflon Katheter Technik von AMPLATZ katheterisiert Letztere Methode hat das Risiko intramuraler oder periaortaler Injektion von Kontrastmittel auf eine zu vernachlässigende Grösse vermindert Diese ergab auch eine höhere Frequenz erfolgreicher Untersuchungen

RÉSUMÉ

Les auteurs ont étudié les complications d une série de 420 aortographies translombaires Cent soixante quinze examens ont été faits par la méthode de ponction percutanée directe à l aiguille et dans les 245 autres cas l aorte a été cathétérisée par la technique de cathéter en teflon d AMPLATZ Cette dernière méthode a réduit à un chiffre negligeable les dangers d injection intramurale et periaortique de moyen de contraste Elle a aussi donné une fréquence plus grande d examens réussis

REFERENCES

AMPLATZ K Translumbar catheterisation of the abdominal aorta Radiology 81 (1963), 927

BEALL A C HENLY W S MORRIS G C CRAWFORD E S COOLEY D A and DEBAKEY M E Translumbar aortography A simple safe technic Ann Surg 157 (1963) 882

BOBLITT D E HIGLEY M M and WOLFMAN E F Roentgen signs of contrast material dissection of aortic wall in direct aortography Amer J Roentgenol 81 (1959) 826

GAYLIS H and LAWS J W Dissection of aorta as a complication of translumbar aortography Brit med J 1956 II p 1141

HAUT G and AMPLATZ K Complication rates of transfemoral and transaortic catheterization Surgery 63 (1968) 594

KINCAID O W Translumbar aortography Sth med J 51 (1958) 455

LINDGREN E Technique of abdominal aortography Acta radiol 39 (1953) 205

MCAFEE J G A survey of complications of abdominal aortography Radiology 68 (1957) 825

SELDINGER S I Catheter replacement of the needle in percutaneous arteriography A new technique Acta radiol 39 (1953) 368

Table 1

The whole material consisting of 58 randomly selected encephalographic examinations Classification as normal or pathologic according to evaluation without measurement

Group	Normal	Patho-logic**	No of cases	Age (years)		No of volume changers	Per cent
				Mean	Range		
I	7	18	25	2	0–8	7	28
II	31	2	33	8	9–17	8	24
Total	38	20	58	5 4/12	0–17	15	25 8

* Primarily classed as normal
Primarily classed as pathologic

could be proved by measurements The volume changers are listed in Table 2 and the average ages and the means of the differences given

Examples of the encephalographic appearances in the a p projections taken before (a) and after the temporal horn filling manoeuvre (b) are illustrated in Figs 2 and 3

Clinical aspects of the volume changers The initial clinical data were supervised and the further course of these cases controlled to evaluate whether they possessed common clinical features The case histories indicated that the group of volume changers was fairly heterogeneous as regards age and symptoms and signs as well as to the presence or absence of recognizable morphologic changes at encephalography The volume changes observed cannot therefore be ascribed to any particular condition of the brain

Clinical aspects of the non changers These 43 cases (74 2 per cent) were grouped according to their essential clinical signs and compared with those from the changer group It must be mentioned however that such a grouping cannot be appropriate in every respect since combinations of symptoms and signs do exist There was e g overlapping between the epilepsy group and those predominately characterized by psychomotoric retardation and mental deterioration associated with brain lesions.

In conclusion it may be stated that no principal differences exist between the changers and non-changers as regards the clinical manifestations of brain disease

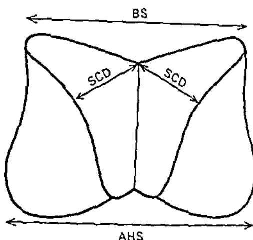


Fig 1 AHS anterior horn span BS body span SCD right or left septum caudate distance the shortest distance from the upper medial angle of the body of the lateral ventricle to the most bulging part of the caudate nucleus

Material Sixty examinations of patients aged up to 16 years were selected at random from a large material of encephalographies 2 had to be discarded because of insufficient filling of the ventricles, 38 of the remaining 58 cases had primarily been assessed as normal and 20 as pathologic The films were scrutinized without previous knowledge of the cases Particular attention was paid to the a p projections in those cases in which a temporal horn filling procedure was performed Cases in which the volume of the anterior parts of the lateral ventricles seemed to have changed after the manoeuvre were only accepted as volume changers when identical projections had been obtained, carefully proved by superposition of the original films or copies The outer contours of the skull, the orbit, the innominate line, the sphenoidal plane and the lesser wings of the sphenoid were used as criteria Cases in which projectional differences of more than 1 mm in the films were present were not used These demands were fulfilled in 15 of the 58 cases in most of which both films corresponded exactly Measurements were obtained in all these 15 cases by conventional methods of the following (1) the anterior horn span (DAVIDOFF & DYKE, 1937, EVANS 1942 and others), (2) the body span (BRUIJN 1959, BURHENNE & DAVIES 1963 TONNUM 1966 and others), (3) the septum caudate distance (TROLAND et coll 1946 LAUBER 1965 and others) The definition of these parameters are given in Fig 1 The whole material divided into two age groups, is presented in Table 1

Results

All the 15 cases suitable for comparison had a varying decrease in volume after the temporal horn filling manoeuvre This was obvious on inspection and

Table 1

The whole material consisting of 58 randomly selected encephalographic examinations. Classification as normal or pathologic according to evaluation without measurement

Group	Normal	Pathologic*	No. of cases	Age (years)		No. of volume changers	Per cent
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I	7	18	25	2	0–8	7	28
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Total	38	20	58	5 4/12	0–17	15	25.8

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Primarily classed as pathologic

could be proved by measurements. The "volume changers" are listed in Table 2 and the average ages and the means of the differences given.

Examples of the encephalographic appearances in the a.p. projections taken before (a) and after the temporal horn filling manoeuvre (b) are illustrated in Figs 2 and 3.

Clinical aspects of the "volume changers". The initial clinical data were supervised and the further course of these cases controlled to evaluate whether they possessed common clinical features. The case histories indicated that the group of "volume changers" was fairly heterogeneous as regards age and symptoms and signs as well as to the presence or absence of recognizable morphologic changes at encephalography. The volume changes observed cannot therefore be ascribed to any particular condition of the brain.

Clinical aspects of the "non-changers". These 43 cases (74.2 per cent) were grouped according to their essential clinical signs and compared with those from the changer group. It must be mentioned, however, that such a grouping cannot be appropriate in every respect since combinations of symptoms and signs do exist. There was, e.g., overlapping between the epilepsy group and those predominately characterized by psychomotoric retardation and mental deterioration associated with brain lesions.

In conclusion it may be stated that no principal differences exist between the "changers" and "non-changers" as regards the clinical manifestations of brain disease.

Table 2

Means and ranges of ages and differences and percentages (AHS anterior horn span BS body span SCD septum caudate distance)

Group	No of cases	Age (years)		AHS (mm)			BS (mm)			SCD right (mm)			SCD left (mm)		
		Mean	Range	Mean	Range	%	Mean	Range	%	Mean	Range		Mean	Range	%
I	7	2.9	8/12–7	1.4	0–2	1.5	0.9	0–3	2.7	3.0	2–6	21	3.7	2–6	24
II	8	11.7	9–16	0.25	0–1	0.005	1.5	0–4	3.6	2.0	1–5	16.3	2.5	1–4	[illegible]
Total	15	7.6	8/12	0.16	0–2	0.98	1.3	0–4	3.2	2.46	1–6	19.3	3.0	1–6	23

Discussion

Linear ventricular distances are, partly, dependent on the projection Changes in angulation of the central beam may project different parts of the ventricles as tangential surfaces Only views falling within a narrow range of projectional variation can be used for such purposes Thus, slight differences in, e g the body span or the septum caudate distance, are frequently obtained if the measurements are performed in films differing but slightly in angulation A further pitfall is incomplete filling of the lateral ventricles, which may produce false dimensions Only examinations with filling to at least the level of the interventricular foramina can therefore be accepted for measurement purposes

The cases reported suggest that another factor really influences the size of certain parts of the lateral ventricles at encephalography and may cause rapid change in the ventricular volume during the short time needed to perform the temporal horn filling manoeuvre Figs 2 and 3 disclose that the volume changes seem to depend on a narrowing of the posterior segments of the anterior horns as well as on that of the anterior parts of the bodies The widths of the anterior horns, as expressed by the anterior horn span, remained however essentially unchanged The parts of the lateral ventricles mentioned are thus generally narrower in the b than in the a films In one case (Fig 3) the superolateral angles of the bodies were almost completely occluded in the b state It would appear that such changes may be easiest explained by a more or less symmetric displacement of the caudate nuclei along lines directed as the septum caudate lines associated with a slight rotational movement of the upper parts towards the middle line The question is how such movements occur



Fig 2 Slight reduction of ventricular volume in (b) Bulging of the septum pellucidum towards the more collapsed side Before (a) and after (b) temporal horn filling

Since there are no contractile elements whatsoever in the brain substance all rapid changes in the shape and volume of the cerebral ventricles are passive and must reasonably be referred to variations in intracranial pressure during the encephalographic procedure Deformations of cerebral surface structures as well as of the ventricles are not infrequently observed during encephalographic examinations particularly in children Separation of the brain surface from the skull bone by subdural collections of gas with deformation of the corresponding parts of the lateral ventricles is a well known complication of encephalography

Surface deformations may occur in very young children even though the gas passes correctly into the subarachnoid space only These consist of a widening of cortical furrows at the highest point e g in the parietal region when the patient is sitting and frontally when supine Such deformations cannot generally be caused by preexisting widening of the subarachnoid space and must undoubtedly be sometimes ascribed to the special conditions present in immature brains that have not yet been myelinated There seems to be reason to believe in a greater capacity for distension of the subarachnoid spaces in young individuals as it is well known that their brains are more easily deformable and of softer consistency than in older subjects Such changes representing artefacts may therefore be misinterpreted as hypoplasias or atrophies

A similar deformation phenomenon is the bulging of the septum pellucidum doubtless the result of a pressure gradient between the lateral ventricles and created by the encephalographic manipulations In the case of a communicating

Table 2

Means and ranges of ages and differences and percentages (AHS anterior horn span, BS body span, SCD septum caudate distance)

Group	No of cases	Age (years) Mean	Range	AHS (mm) Mean	Range	%	BS (mm) Mean	Range	%	SCD right (mm) Mean	Range	%	SCD left (mm) Mean	Range	%
I	7	2.9	8/12–7	1.4	0–2	1.5	0.9	0–3	27	3.0	2–6	21	3.7	2–6	24
II	8	11.7	9–16	0.25	0–1	0.005	1.5	0–4	36	2.0	1–5	16.3	2.5	1–4	22
Total	15	7.6	8/12–	0.46	0–2	0.98	1.3	0–4	32	2.46	1–6	19.3	3.0	1–6	23

Discussion

Linear ventricular distances are, partly, dependent on the projection. Changes in angulation of the central beam may project different parts of the ventricles as tangential surfaces. Only views falling within a narrow range of projectional variation can be used for such purposes. Thus, slight differences in, e.g. the body span or the septum caudate distance, are frequently obtained if the measurements are performed in films differing but slightly in angulation. A further pitfall is incomplete filling of the lateral ventricles, which may produce false dimensions. Only examinations with filling to at least the level of the interventricular foramina can therefore be accepted for measurement purposes.

The cases reported suggest that another factor really influences the size of certain parts of the lateral ventricles at encephalography and may cause rapid change in the ventricular volume during the short time needed to perform the temporal horn filling manoeuvre. Figs 2 and 3 disclose that the volume changes can depend on a narrowing of the posterior segments of the anterior horns as well as on that of the anterior parts of the bodies. The widths of the anterior horns, as expressed by the anterior horn span, remained however essentially unchanged. The parts of the lateral ventricles mentioned are thus generally narrower in the b than in the a films. In one case (Fig 3) the superolateral angles of the bodies were almost completely occluded in the b state. It would appear that such changes may be easiest explained by a more or less symmetric displacement of the caudate nuclei along lines directed as the septum caudate lines, associated with a slight rotational movement of the upper parts towards the middle line. The question is how such movements occur.

cavum septi pressure differences may exist between the cavum and the lateral ventricles, resulting in biconcave or biconvex bulging Such deformations are relevant for this discussion as they demonstrate the effect of pressure differences within one and the same system of gas- and fluid filled cavities if the communication becomes blocked

Displacement of the caudate nuclei in the cases reported as representing part of the lateral walls of the lateral ventricles may also be caused by a pressure gradient The theory must therefore be accepted that a pressure difference is created and maintained during the manoeuvre performed to fill the temporal horns The degree of temporal horn filling achieved seems to be of no consequence, gas escapes to the subarachnoid compartments when the head is lowered and turned or a somersault is performed If the ventricles were rigid, a loss of their gas content would not be possible unless an inflow of a corresponding volume of fluid occurred simultaneously Such a reverse flow is obviously not always compensatory with the result that the ventricular walls come together causing a collapse

The question as to whether one of the two appearances may be accepted as representing the normal state cannot be answered with certainty There are three main possibilities (1) The normal state as in the a figures the b appearance would then represent a ventricular collapse caused by decreased pressure (2) The normal state as in the b appearance, the wider a variant would then represent ventricular dilatation due to an increase in pressure (3) The truth lies somewhere between the extremes

The diagnosis would be unaffected by the state of expansion presented by the ventricles at encephalography provided that they were all equally expanded or collapsed Since, at least in children that does not obtain those measurement liable to considerable changes have to be regarded as inconstant parameters these are headed by the septum caudate measurement with changes of 19 and 23 per cent on the two sides respectively The variability of the body span although comparably small (on an average 3 per cent) may also cause difficulties if fixed borderlines are used for the assessment The degree to which the body span is a sensitive parameter of ventricular size is then another matter This also applies to the anterior horn span which changes very little (less than 1 per cent) and seems to be the most constant measurement The work of LAUBER (1965) as well as preliminary calculations by the present author indicate that the septum caudate measurement is the most reliable parameter of ventricular size a view which is also supported by theoretic considerations regarding the mechanism of ventricular enlargement The variability of the septum-caudate distance due to artifical influences at encephalography seems to reduce its value however

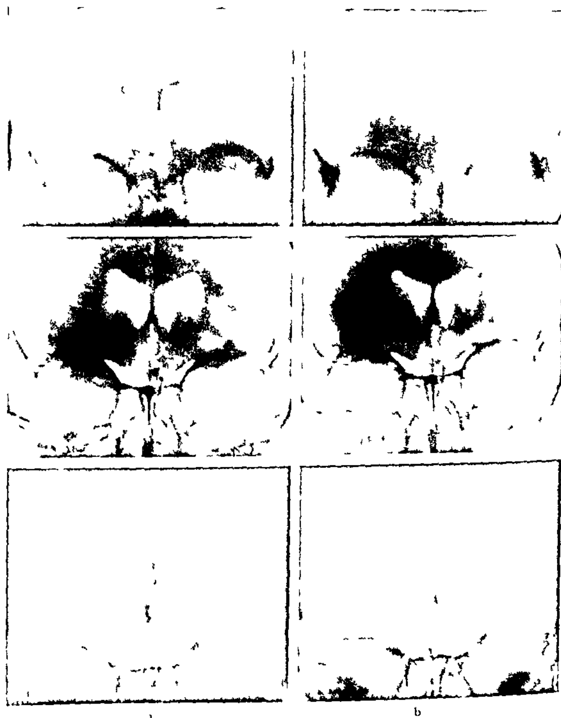


Fig 3 Reduction of ventricular volume in (b) is clearly recognizable The suction effect is slightly asymmetric in the top figures The other figures reveal varying degrees of symmetric collapse The superolateral angles are generally less rounded in the b appearances The appearance in the right bottom figure might be misinterpreted as being due to microventricula

during the initial filling procedure. This assumption was strengthened by the observations made by OBERSON et coll. (1969) who reported progressive dilatation of the fourth ventricle during the first 10 minutes of the filling procedure (the average increase in height was 1.8 mm).

The degree of the gas inflow distension of the lateral ventricles is, in contrast to the easily measureable height of the fourth ventricle, impossible to assess; more complete filling and a change in position is required and the ventricles may already be distended. The problem of the usual width of the lateral ventricles cannot be resolved by the encephalographic method and thus remains open to discussion. On the other hand, if measurements in selected series or for correlative purposes are intended, they should preferably be made in the first a.p. films. Such a material would then be homogenized as the collapse variat ors are excluded. As regards *the fourth ventricle, the phenomenon of* the volume variation at encephalography was, for the first time, taken into consideration in the correlative investigation published by GREITZ & CREPE (1971).

Conclusions

Fluctuations in width of parts of the ventricular system may occur during the encephalographic examination of children and adolescents; it occurred in 75 per cent of the present material. It appears as though a collapse of the lateral walls due to the temporal horn filling manoeuvre is produced in a much higher percentage. This is probably a common phenomenon provided that the physical conditions necessary for the evacuation of the ventricles (patent cisterns and subarachnoid spaces) exist. No correlation appeared to exist between that phenomenon and the clinically diagnosed condition of the brain nor the age. The changes are due to a more or less symmetric displacement of the caudate nuclei and the adjacent parts of the lateral walls. The cause for the phenomenon is to be sought in a pressure gradient created by a loss of gas during the temporal horn filling manoeuvre; it reflects the elasticity of the brain and its capability of rapid changes in shape as a response to pressure forces. This kind of change in ventricular volume is probably different from the dilatation sometimes observed in the 24 hour encephalograms.

Among the measurements commonly used as parameters for the size of the lateral ventricles that of the septum caudate is the most inconstant one because of possible changes (averages) of as much as 19 and 23 per cent on the right and left side respectively; individual changes of more than 40 per cent may however occur. Pressure dependent alterations of such a degree naturally influence the assessment of the encephalographic examination. The average

A mention must also be made on the frequency of the collapse phenomenon (columns 6 and 7, Table 1) As previously stated, only those cases in which the projections were identical were evaluated, there were certainly more cases in which the volumes had changed although this was difficult to prove There was also a percentage of cases in which a temporal horn filling manoeuvre was not performed because filling had occurred spontaneously due to an excess of intraventricular gas

In this connection mention should be made of a striking similarity that existed between the b appearance of, e g the case demonstrated in Fig 3, and the condition that was termed Mikroventrikulie by KEHRER (1948) A similar case was reported and illustrated by DECKER & BACKMUND (1970), a repeat examination carried out 2 years later revealed that the ventricles were completely normal in size True 'microventriculia', if existing is thought to represent an organic, developmental state of the brain (the presence of brain swelling has to be excluded clinically and by the absence of compression of the basal cisterns), it is therefore hard to believe that the ventricle as evident in a p views should become so small and yet again return to normal The age at which optimal relation between the size of the ventricles and that of the skull is reached is unknown, this means the largest possible brain mass and a minimum volume of the ventricular system and probably varies individually Present knowledge about the brain—skull relations during development cannot perhaps exclude the possibility of 'microventricula' of that kind (symmetrically affecting the anterior parts of the lateral ventricles) There may consequently be justification in asking whether such appearances could have been produced in a manner similar to that in the present cases

All authors who have noticed an increase in size of the lateral ventricles after encephalography have done so in films taken more than 24 hours later (FRIEDMAN et coll 1928, EVANS 1942, SCHATZKI et coll 1947, LINDGREN 1951) or at three and more hours (COBBLL & BRACKETT 1965, LE MAY 1967) The latter author also discussed the mechanisms suggested by previous workers and the connected problem whether or not the 24 hour size of the ventricles could be regarded as the true one, but reached no conclusion Only one author seems to have noticed a decrease in size of the lateral ventricles at the end of pneumography (JIROUT 1956) This author, however, explained the phenomenon by reactional cerebral oedema due to the irritative effect of the air

The 3 and 24 hour dilatation of the ventricles mentioned by the above authors was diagnosed by measuring the anterior horn span, a measurement that remained essentially unchanged in the present series This is indicative of the different cause and mechanism of the volume changes working at encephalography, and afterwards It must be supposed that there exists a blow up effect

ZUSAMMENFASSUNG

Das Phanomen der raschen Volumensanderung von Teilen des cerebralen Ventrikel systems bei der Encephalographie wird hinsichtlich Ursache und Mechanismus diskutiert Es wird auf die Bedeutung dieses Phanomens fur die Beurteilung der Encephalographien besonders bei Kindern und Jugendlichen hingewiesen

RÉSUMÉ

L auteur etud e la cau e et le mecanisme de la modification rapide de volume de certaines parties d l systeme ventriculaire cerebral au cours de l encephalographie Il attire l atten tion sur l interet de ce phenomene pour interpreter les encephalographies en particul er chez les enfants et les adolescents

REFERENCES

BRUIJN G W Pneumoencephalography in the diagnosis of cerebral atrophy A quantitative study H J Smits Utrecht 1959

BURHENNE H J and DAVIES H The ventricular span in cerebral encephalography Amer J Roentgenol 90 (1963) 1176

COBBLE S P and BRACKETT C E Changes in the ventricular size during stereotaxic surgery Amer J Roentgenol 95 (1965) 890

DAVIDOFF L M and DYKE C C The normal encephalogram Lea & Febiger Detroit 1937

DECKER K und BACKMUND H Padiatrische Neuroradiologie Georg Thieme Verlag Stutt gart 19 0

EVANS JR W A An encephalographic ratio for estimating ventricular enlargement and cerebral atrophy Arch Neurol Psychiat 47 (1942) 931

— An encephalographic ratio for estimating the size of the cerebral ventricles Further ex perience with serial observations Amer J Dis Child 64 (1942) 820

FRIEDMAN E D SNOW W and KASANIN J J Experiences with encephalography via the lum bar route Arch Neurol Psychiat 19 (1928) 762

GREITZ T and GREPE A Encephalography in the diagnosis of convexity block hydrocephalus Acta radiol Diagnosis 11 (1971) 232

JIROUT J Changes in the size of the subarachnoid spaces after the insufflation of air Acta radiol 46 (1956) 81

KEHRER F A Die konstitutionelle Verkleinerung der Hirnventrikel (Mikroventrikulie) und ihre nosologische Bedeutung Arch Psychiat 118 (1948) 430

— Zur nosologischen Bedeutung der Mikroventrikulie mit besonderer Berucksichtigung der Migrane Dtsch Z Nervenheilk 163 (1950) 555

LAUBER H Das Pneumoencephalogramm Messverfahren bei Erwachsenen Johan Ambrosius Barth Munchen 1965

LE MAY M Changes in ventricular size during and after pneumoencephalography *Radiology* 88 (1967) 57

LINDGREN E Some aspects on the technique of encephalography Acta radiol 31 (1949) 161

— Encephalography in cerebral atrophy Acta radiol 35 (1951) 277

LONNUM A The clinical significance of central cerebral ventricular enlargement Universi tetsforlaget Oslo 1966

changes in the other measurements, the body span and the anterior horn span, are small and, at least with the latter, negligible

It is probable that in children and adolescents the encephalographic appearances suggesting a condition called microventriculia may occasionally be caused by artefacts due to a low pressure created at the encephalographic procedure A collapse of the lateral ventricles need not to be symmetric A predominantly unilateral collapse is recognisable by the bulging of the septum pellucidum The fact that the anterior horn span remained essentially unchanged in all the present cases may be explained by a greater degree of rigidity of the anterior walls, due to the surrounding brain matter and a greater weakness of the lateral walls of the bodies of the lateral ventricles

The encephalographic procedure should always be the conventional one, which means that the patient after being examined sitting should be lowered to the supine position If this step be omitted to save time and the somersault or temporal horn filling manoeuvre be performed immediately, a considerable risk exists that a false idea of the size of the lateral ventricles, due to their collapse, may be obtained

Addendum in proof

A number of adult cases with ventricular volume changes during encephalography have been observed since the preparation of this communication

A paper on the same subject has been published by OIGAARD The results are similar as regards the tendency but differ in degree For instance the decrease in size of the septum caudate measurement proved to be 10 to 20 per cent in 80 per cent of the cases as well as in 70 per cent of the frontal horn widths These figures have to be compared with the 19 and 23 per cent average decrease in the septum caudate measurement and less than 1 per cent decrease in the anterior horn span in the present material The difference in these measurements may be partly explained by the selection of the present material which probably comprises cases that have changed more On the other hand the present values are more reliable since no projectional deviations were accepted As regards the decrease in the anterior horn span the figures disagree considerably The encephalographic procedure was not described by OIGAARD and nothing was mentioned about the manipulations usually carried out between shortly after the insufflation of the gas and at the end of the examination a time given as 20 to 30 minutes It must therefore be presumed that these factors were not considered in explaining the cause and mechanism for the phenomenon OIGAARD s conclusion is therefore in accordance with the original theory of JIROUT

SUMMARY

The phenomenon of a rapid change in volume of parts of the cerebral ventricular system at encephalography is discussed with regard to the cause and mechanism Attention is drawn to the significance of this phenomenon for the assessment of encephalographies especially in children and adolescents

ZUSAMMENFASSUNG

Das Phanomen der raschen Volumensanderung von Teilen des cerebralen Ventrikelsystems bei der Encephalographie wird hinsichtlich Ursache und Mechanismus diskutiert. Es wird auf die Bedeutung dieses Phanomens fur die Beurteilung der Encephalographien besonders bei Kindern und Jugendlichen hingewiesen

RÉSUMÉ

L auteur etudie la cause et le mecanisme de la modification rapide de volume de certaines parties du systeme ventriculaire cerebral au cours de l encephalographie. Il attire l attention sur l interet de ce phenomene pour interpreter les encephalographies, en particulier chez les enfants et les adolescents

REFERENCES

BRUIJN G W Pneumoencephalography in the diagnosis of cerebral atrophy A quantitative study H J Smits Utrecht 1959
BURHENNE H J and DAVIES H The ventricular span in cerebral encephalography Amer J Roentgenol 90 (1963) 1176
COBBLE S P and BRACKETT C E Changes in the ventricular size during stereotaxic surgery Amer J Roentgenol 95 (1965) 890
DAVIDOFF L M and DYKE C G The normal encephalogram Lea & Febiger Detroit 1937
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The encephalographic procedure should always be the conventional one, which means that the patient after being examined sitting should be lowered to the supine position If this step be omitted to save time and the somersault or temporal horn filling manoeuvre be performed immediately, a considerable risk exists that a false idea of the size of the lateral ventricles, due to their collapse, may be obtained

Addendum in proof

A number of adult cases with ventricular volume changes during encephalography have been observed since the preparation of this communication

A paper on the same subject has been published by OIGAARD The results are similar as regards the tendency but differ in degree For instance the decrease in size of the septum caudate measurement proved to be 10 to 20 per cent in 80 per cent of the cases as well as in 70 per cent of the frontal horn widths These figures have to be compared with the 19 and 23 per cent average decrease in the septum caudate measurement and less than 1 per cent decrease in the anterior horn span in the present material The difference in these measurements may be partly explained by the selection of the present material which probably comprises cases that have changed more On the other hand the present values are more reliable since no projectional deviations were accepted As regards the decrease in the anterior horn span the figures disagree considerably The encephalographic procedure was not described by OIGAARD and nothing was mentioned about the manipulations usually carried out between shortly after the insufflation of the gas and at the end of the examination a time given as 20 to 30 minutes It must therefore be presumed that these factors were not considered in explaining the cause and mechanism for the phenomenon OIGAARD's conclusion is therefore in accordance with the original theory of JIROUT

SUMMARY

The phenomenon of a rapid change in volume of parts of the cerebral ventricular system at encephalography is discussed with regard to the cause and mechanism Attention is drawn to the significance of this phenomenon for the assessment of encephalographies especially in children and adolescents

FROM THE DEPARTMENT OF NEURORADIOLOGY (DIRECTOR A CALABRO), CARDARELLI HOSPITAL NAPLES ITALY

ECG CHANGES IN VERTEBRAL ANGIOGRAPHY BY PUNCTURE AND RETROGRADE INJECTION OF THE BRACHIAL ARTERY

by

A PALMIERI

Cerebral angiography generally produces variations in the ECG Investigations in human subjects and laboratory animals have indicated that the injection of contrast medium into the carotid artery almost always causes alterations in the heart rate usually bradycardia (BROMAN & OLSSON 1948 FOLTZ et coll 1952 GREITZ & WEISS 1956 LINDGREN & TORNELL 1958 LINDGREN 1959 EINSTEIN et coll 1959 FISCHER et coll 1962 LUNDERVOLD & ENGESET 1966 LODIN & OTTANDER 1967 LODIN 1968)

Few reports on ECG changes in vertebral angiography have however appeared GREITZ (1956) recorded an increase in the heart rate following an injection of Triurol into the vertebral artery and concluded that the phenomena are different from those observed in carotid angiography LODIN (1968) reviewed sixty six vertebral angiographies performed in 60 patients in whom the injection of contrast medium (5 to 6 ml Urografin 60 %) was performed by catheter in 39 and by direct puncture in 21 patients He suggested that ECG changes are more frequent than when the injection is made into the carotid artery and

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OBERSON R., CANDARDJIS G. and RAAD N. Height of fourth ventricle. Normal variabili[ty] during pneumography. Acta radiol. Diagnosis 9 (1969) 193
OIGAARD A. Changes in ventricular size during pneumoencephalography. Neuroradiology (1971) 8
ROBERTSON L. G. A method of encephalography. Surgery 19 (1946), 810
SCHATZKI R., BAXTER D. H. and TROLAND C. L. Second day encephalography with particular reference to the size of the ventricles. New Engl. J. Med. 236 (1947) 419
TROLAND C. L., BAXTER D. H. and SCHATZKI R. Observations on encephalographic findings in cerebral trauma. J. Neurosurg. 3 (1946) 390

Table 2

Mean, maximum and minimum values of heart rate increases and decreases (percentage) during the first minute

Seconds	Tachycardia			Bradycardia		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
10	+ 8 2	21 5	4 6	− 9 6	23 0	2 0
0	−19 0	65 0	5 2	−14 4	9 2	2
30	+21 5	63 0	4 3	− 9	5	1 7
40	+17 7	47 0	3 8	− 6 2	19 0	1 3
50	+12 7	35 0	3 6	− 3 0	14 0	0 8
60	+ 7 6	21 0	2 3	− 4 0*	—	—

* Only one patient

An injection of 1 mg Fargan and 0 5 mg Atropine was administered (i m) before induction of anesthesia (i v) with Thiopentone (100 to 600 mg i v) The trachea was intubated with a cuffed tube and ventilation controlled with a ventilator delivering oxygen and nitrous oxide The brachial artery was punctured at the inner aspect of the left elbow in 27 and the right elbow in 3 patients during injection of the right brachial artery the carotid artery of the same side was compressed In one of the three patients the compression was incomplete (the contrast medium was visible in the carotid system) bradycardia was not recorded Two routine serial lateral and frontal films were obtained about 25 to 30 mg sodium iothalamate (Conray 60 %) being injected over 4 to 6 s for each view The first ECG recording with all the lead derivations — basal ECG — was obtained when the patient was already under general anesthesia and when the puncture in the artery had been made to determine the general cardiovascular conditions Before injection of the contrast medium a D2 recording was started to determine and evaluate possible ECG changes. This recording lasting an average of 10 seconds was repeated continuously during and after the injection of the contrast medium for 1 minute A second and third 10 second recording was made at the end of the second and third minute The parameters investigated in all the recordings were the P wave the QRS complex the T wave the S—T segment as well as the QTc and the heart rate The ECG obtained during the continuous recording was divided into reading sections each corresponding to a 10-second interval from the beginning of the injection

Table 1

Heart rate changes (number of patients) referred to the time of the beginning, maximum and return to basal values

Seconds	Beginning	Maximum	Return to normal
10	8		
20	2	3	
30		24	
40		2	
50		1	
60			8
120			16
180			
–			6*

* A new heart rate was established with an increase of about 10 per cent compared to the initial conditions this increase disappeared gradually in about 10 min in 5 patients in another the increase persisted until the patient recovered from the anesthesia (about 20 min)

that tachycardia occurs in a higher percentage (48 per cent) of patients Neither the age nor the examination technique had any influence on the results LODIN interpreted this difference as a consequence of the penetration of the contrast medium into the different areas supplied by the carotid and vertebral vessels

The ECG response of 30 patients subjected to vertebral angiography by percutaneous puncture and retrograde injection of the brachial artery will be discussed in this communication

Material and Methods Thirty patients, eighteen men and twelve women, aged between 12 and 68, formed the material Four of these hade space occupying lesions of the posterior fossa, one multiple sclerosis another bilateral carotid thrombosis and 2 marked arteriosclerotic changes in the basilar system Fourteen patients had subarachnoid hemorrhage, and of these 2 had an arterio venous aneurysm supplied by the carotid system as well as by the basilar system while another had a saccular aneurysm of the internal carotid artery No pathology was found at angiography in the remaining 11 patients Eight patients had clinical signs of slightly increased intracranial pressure but negative angiographic findings

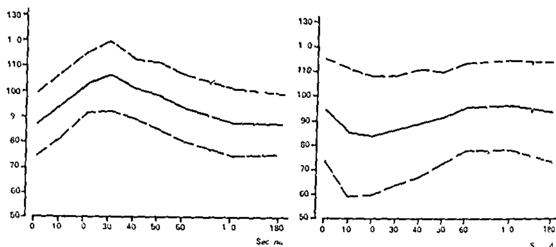
incomplete right bundle branch block. Eighteen patients with a normal basal ECG had no changes. As regards the QTc there were no changes in 29 patients and only in one with marked S—T and T wave sagging in the basal ECG did this for about 2 min appear to be increased. The ECG changes in the individual patient were reproduced following subsequent injections of contrast medium, even if there were slight differences in intensity. No changes were ever observed in the shape and duration of the P and QRS deflections.

Discussion and Conclusions

This investigation suggests that the ECG changes occurring during vertebral angiography by percutaneous puncture and retrograde injection of the brachial artery have never been clinically relevant, even when obvious alterations in the basal ECG have been present. The changes had completely disappeared within 3 min excepting in 6 patients in whom a slight increase in the heart rate persisted; clinically appreciable hemodynamic disturbances were never observed.

Tachycardia occurred in 90 per cent of the patients. The percentage is higher than in LODIN's series (48 per cent). The appearance or increase of repolarization abnormalities (10 per cent) was also higher than reported by LODIN.

The pathogenesis of such changes is likely to depend upon stimulation of certain vaso-active areas of the brain. BYER et coll. (1947) described the modification in the T wave and the QT interval in a group of patients with encephalopathy. Successively other authors (e.g. BURCH et coll. 1954, MILLAR et coll. 1968) have made detailed reports of ECG appearances in patients with cerebrovascular accidents such as T waves of considerable amplitude and width, long QT intervals, large U waves and rhythm disturbances. BORDICK et coll. (1969), who examined ECG tracings of 12 children undergoing encephalography, observed transient changes in the T and P waves as well as arrhythmia with a return to normal after six hours in each subject. The effects of the injection of a contrast medium into the carotid artery on the heart rate and blood pressure have been recorded by BROMAN & OLSSON from experiments in laboratory animals, GREITZ on his clinical observations and LINDGREN and LINDGREN & TORNELL from animal experiments have concluded that ECG changes are a result of the action of the contrast medium upon certain structures of the brain. The hypothalamus, the brain stem, the midbrain and the medulla oblongata are all possible areas from which the responses may be elicited. This has been discussed by LUNDERVOLD & ENGESET, FISCHER et coll. and LODIN. FISCHER et coll. in carotid angiography and LUNDERVOLD & ENGESET in a mixed carotid and vertebral angiography material reported marked bradycardia when



Mean values and standard deviations of heart rates with tachycardia (left) and bradycardia (right)

Results

Eighteen basal ECG were classified as normal and twelve were pathologic, in no patient was the ECG unaffected. All recordings revealed changes in the heart rate with tachycardia in 27 (90 per cent) and bradycardia in 3 (10 per cent) patients. The 3 patients with a bradycardial reaction were examined by left brachial artery injections: one had clinical and angiographic evidence of vertebro-basilar arteriosclerosis and the remaining two patients, with subarachnoid haemorrhage and a probable posterior fossa tumour, respectively, appeared normal at angiography.

Every patient had the same reaction to the various injections. The course of the changes in heart rate are listed in Table 1 and their values in Table 2. Mean values with standard deviations appear in the Figure.

Repolarization abnormalities such as sagging S–T and T waves were observed in 3 patients, in 2 with an increase to a maximum at 30 to 40 s and a slow return to normal within 3 min. A 12-year-old child with a ventriculo-atrial shunt and an inoperable posterior fossa tumour had a sagging S—T and flattened T wave around the 25th s; these disappeared within 3 min. Arrhythmia was evident in 2 other patients, in one in the form of ectopic premature beats and in the other as right sinus arrhythmia lasting about 10 to 50 s. Another 52-year-old patient had premature supraventricular beats from the 20th s covering nearly the entire 2nd min with an average of one premature supraventricular beat every 8 to 10 heart beats. In 5 patients the basal ECG remained unvaried, except for the increase in heart rate, as happened in one patient with

RÉSUMÉ

Description des modifications électrocardiographiques principalement des tachycardies chez 30 malades au cours de l'angiographie vertébrale par ponction percutanée et par injection rétrograde à partir de l'artère humérale. Ces modifications semblent être dues à un effet sur certaines aires vasomotrices cérébrales. Les différences entre les modifications observées au cours de l'angiographie carotidienne et de l'angiographie vertébrale doivent peut-être être attribuées à des effects antagonistes sur différentes structures.

REFERENCES

BURDICK J M, GELBAND H, STEEG C N and FASKER W. Electrocardiographic changes in children undergoing pneumoencephalography. Neurology 13 (1963) 1217

BROMAN T and OLSSON O. The tolerance of cerebral blood vessels to a contrast medium of the diodrast group. An experimental study of the effect on the blood brain barrier. Acta radiol 30 (1948) 326

BURCH G E, MEYERS R and ABILDSKOV J A. A new electrocardiographic pattern found in cerebrovascular accidents. Circulation 9 (1954) 719

BYER E, ASHMAN R and TOTH L A. Electrocardiogram with large upright T wave and long Q T intervals. Amer Heart J 33 (1947) 796

EPSTEIN J A, HOFFMAN I and EPSTEIN B S. Electrocardiographic alterations observed during percutaneous cerebral angiography. Iodopyracet (Diodrast) and diatrizoate (*Hypaque*). Arch Neurol Psychiat 81 (1959) 142

FISCHER H W, ECKSTEIN J W and PERRET G. Comparison of the cardiovascular effects of contrast media in cerebral angiography in man. J Neurosurg 19 (1962) 343

FOLTZ E L, THOMAS L B and WARD A A. The effects of intracarotid diodrast. J Neurosurg 9 (1952) 68

GREITZ T. A radiologic study of the brain circulation by rapid serial angiography of the carotid artery. Acta radiol (1956) Suppl No 140

— and WEISS S. EEG and ECG in cerebral angiography with sodium diatrizoate (Hypaque) and *methylglucamine diprotrizoate (Miokon)*. *Acta radiol 52 (1959)* 145

LINDGREN P. Carotid angiography with tri-iodobenzoic acid derivatives. A comparative experimental study of the effects on the systemic circulation in cats. Acta radiol 51 (1959) 353

— and TORNELL G. *Blood pressure and heart rate responses in carotid angiography* with sodium acetrizoate (Triurol). An experimental study in cats. Acta radiol 50 (1958) 160

LOFIN H. Electrocardiograms on vertebral angiography. Acta radiol Diagnosis 7 (1968) 117

— and OTTANDER H G. Electrocardiograms on carotid angiography with Urografin. Acta radiol Diagnosis 6 (1967) 519

LUNDERVOLD A and ENGESET A. Polygraphic recordings during cerebral angiography. Acta radiol Diagnosis 5 (1966) 68

MILLAR K and ABILDSKOV J A. Notched T waves in young persons with central nervous system lesions. Circulation 37 (1968) 597

the contrast medium filled the posterior cerebral artery. They explained these effects as due to the influence of the contrast medium on the hypothalamus or structures supplied by this artery. LODIN concluded from his vertebral angiography material that tachycardia was the most frequent change and explained that this phenomenon is a consequence of the action of the contrast medium on the medulla oblongata which he considered the seat of vasomotor reactive areas. In agreement with LODIN tachycardia was by far the most frequent finding, 90 per cent in the present series. This is more likely the result of an effect on lower structures (most likely at the level of the medulla oblongata and supplied almost exclusively by the vertebro-basilar system) than due to the action of the contrast medium on a structure fed by the posterior cerebral artery. The explanation is consistent with the observations made by FISCHER et coll. and LUNDERVOLD & ENGLSET according to whom a higher incidence of bradycardia occurred in carotid angiography with filling of the posterior cerebral artery. On the other hand, the mechanism of bradycardia during vertebral angiography is still difficult to explain but may be attributed to individual variations or different functional states of the vasomotor areas.

There would therefore appear to be justification in concluding that: (1) Cerebral vasomotor areas doubtless exist, (2) many probably being antagonistic, (3) and located in different structures, and (4) the method of introducing the contrast medium (by direct injection into the vertebral artery, by a catheter via the femoral or brachial artery or by retrograde injection of the brachial artery) fails to play a determining role, at least as regards the nature of the ECG phenomena evoked.

SUMMARY

Electrocardiographic changes in 30 patients in vertebral angiography by percutaneous puncture and *retrograde injection of the brachial artery* are described. Tachycardia was the dominant finding. The changes appeared to be due to an effect on certain cerebral vasomotor areas. The differences between the changes observed during carotid and vertebral angiography may perhaps be attributed to antagonistic effects on different *structures*.

ZUSAMMENFASSUNG

Elektrokardiographische Veränderungen, hauptsächlich Tachykardie, bei 30 Patienten bei der Vertebralisangiographie durch perkutane Punktion und retrograde Injektion der Arteria brachialis werden beschrieben. Diese scheinen auf dem Effekt auf gewisse cerebrale vasomotorische Gebiete zu beruhen. Die Unterschiede zwischen den beobachteten Veränderungen während der Karotis- und Vertebralisangiographie können vielleicht auf antagonistische Effekte von verschiedenen Strukturen zurückgeführt werden.

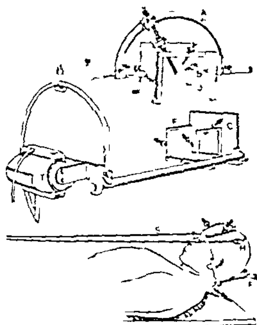


Fig. 1. Stereotaxic instrument of Laitinen as applied in the present investigation. Coordinate frame with cross-bars (B) to support semicircular arc (A) with guide (C) for electrodes [illegible]. The coordinate frame (F) is connected to the roentgen tube (T) by a rigid coupling arm. The cassette (C) is attached to the frame with magnets. Fixation of coordinate frame (F) to the skull. The head is held in position by two struts (S) attached to the skull with hooks (H).

Material and Methods. The investigation was carried out in cadavers of mostly elderly patients without clinical signs or symptoms indicating intracranial disease. The absence of pathology in the posterior fossa was confirmed by the radiologic procedure employed.

Central ventriculography with a water soluble contrast medium (Methyl glucamine Conray 60 %, or Isopaque Cerebral) was performed to evaluate the displacement of the ventricular system. A needle was introduced stereotaxically into the third ventricle and with the body supine the contrast medium flowed freely down into the aqueduct and the fourth ventricle (CORRALES & GREITZ 1972). An injection was also made into the cisterna magna to fill the cisterns of the posterior fossa by the technique of LILIEQUIST (1959) with the body prone; about the same amount of a water soluble contrast medium or a suspension of barium sulfate with 2 per cent gelatin was injected after the removal of 30 to 60 ml of cerebrospinal fluid.

Special techniques have been developed to carry out postmortem vertebral angiography and posterior fossa phlebography in the cadaver with the posterior fossa intact (MOLLER 1972) and employing a barium gelatin medium. These techniques have allowed selective filling of the vertebro-basilar arterial system and complete or almost complete outlining of all angiographically relevant

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STEREOTAXIC METHODS IN THE INVESTIGATION OF EXPERIMENTALLY PRODUCED INTRACRANIAL DISPLACEMENTS

by

T GREITZ, M CORRALES and A MÖLLER

Recent developments in stereotaxic methods in neurologic surgery such as stereotaxically controlled diagnostic punctures, therapeutic punctures and radio surgery procedures have increased the demand for the exact pre-operative localization of expanding lesions. This can be met with greater success in supratentorial lesions than in those of the posterior fossa. Examinations based on post mortem ventriculography in experimentally produced balloon tumours have indicated that a more differentiated localization may be obtained in clinical ventriculography or encephalography than has previously been possible (CORRALES & GREITZ 1972). The introduction of balloon catheters intracranially in cadavers renders it possible to create expanding lesions that are well defined in size and site. Stereotaxic techniques would be of advantage for the exact placing of the balloons. The purpose of this investigation was to determine whether such techniques would allow accurate evaluation of experimentally produced displacements of intracranial arteries, veins, cisterns and ventricular cavities.

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Fig 3 Postmortem phlebography Subtraction films The vascular displacement caused by the balloon *tumour* (B) is evident The vessels appear in white before (⟶) and black after (⟶ displacement.

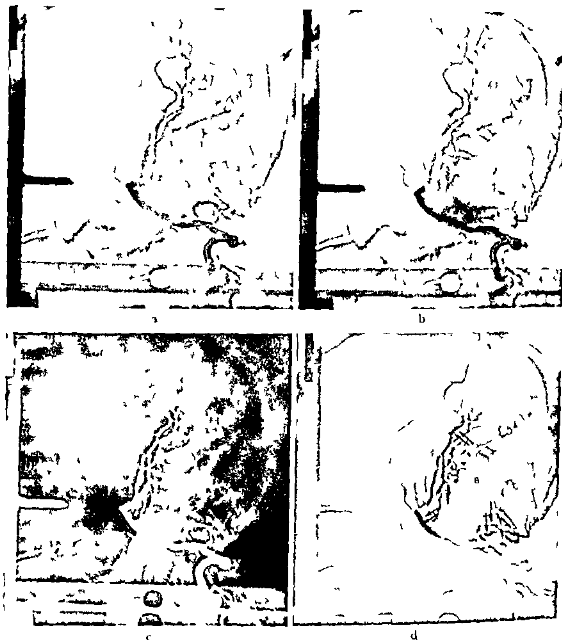


Fig. 2 Subtraction technique in postmortem vertebral angiography *for vascular* displacements produced by an experimental balloon tumour a) Before displacement b) After displacement c) Reversed copy of (a) (mask) d) Result of subtraction by combining (b) and (c) B = balloon Inferior displacement of the ipsilateral posterior inferior cerebellar artery *anterior* displacement of the basilar artery and superior displacement of the posterior cerebral artery are now obvious These vessels appear white before (→) and black after displacement (⟶)

posterior fossa veins After inflation of the balloon i e the experimental tumour, the cisterns were filled with gelatin to secure an unchanged position of the contained vessels The radiographic examination in the cadaver being completed

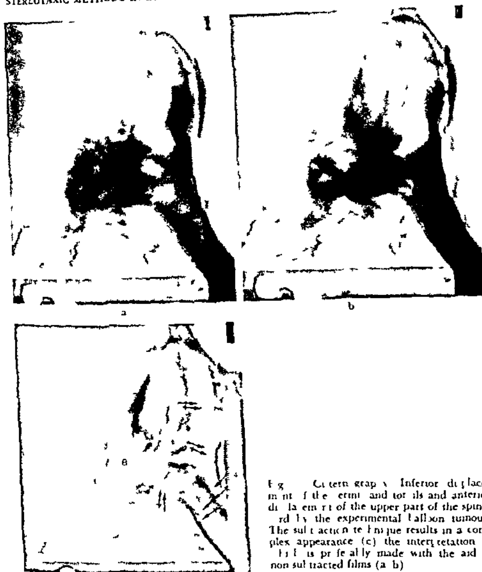


Fig Cisternography Inferior displacement of the vermis and tonsils and anterior displacement of the upper part of the spinal cord by the experimental balloon tumour The subtraction technique results in a complex appearance (c) the interpretation of which is preferably made with the aid of non subtracted films (a b)

vessels When the balloon was at the target point chosen films were exposed at different stages of its insufflation with about 20 ml of air fully inflated it reached a diameter of about 3 cm The subtraction technique (ZIEDSES DES PLANTES 1935 HORENSTEIN et coll 1964 RUGGIERO & MAZZACURATI 1967 RUGGIERO & DETTORI 1967) was used to record the displacement in an objective manner (Figs 2 3 4 5)

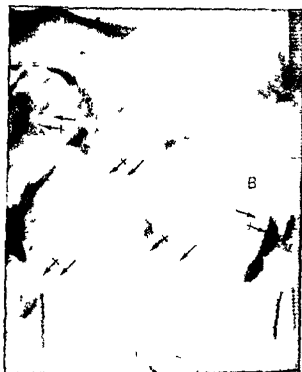


Fig. 4. Postmortem ventriculography. Balloon tumour in the B3 position (CORRALES & GREITZ 1972) producing anterior displacement of the aqueduct, fourth ventricle and anterior surface of the pons; compression of the cisterna magna due to inferior displacement of the vermis and tonsils and antero-superior displacement of the posterior part of the third ventricle are also present. Position before (→) and position after (→) inflation of the balloon.

the specimen, including the whole posterior fossa with the tentorium and the skull base, was removed in one piece, mainly in accordance with the technique earlier used by GREITZ (1969) for the examination of the basal cisterns. The specimen was then fixed in formalin.

The stereotaxic method employed was that of LEKSELL (1949, 1951, 1966). The instrument consists of a co-ordinate frame and a semi-circular arc, designed to guide electrodes or needles to the target point in the centre of the arc from any point on the surface of the sphere circumscribed by the arc. The co-ordinate frame is connected to a small roentgen tube (90 kV, 15 mA, 50 Hz) by a rigid coupling arm, the cassettes being attached to the frame by magnets (Fig. 1). The co-ordinate frame was fixed to the skull of the cadaver and the frame position was chosen to allow lateral and half axial views corresponding to those used clinically. The first set of films was obtained after the injection of the contrast medium but before the introduction of the balloon. Differences in size and distortion due to the short distance were corrected by means of a geometric diagram; the co-ordinates were read off directly on the instrument scale in the films. A burr hole was drilled in the skull and the balloon catheter, stiffened with a mandrin, was introduced by means of a metallic guide through a preformed channel made through the dura, the brain tissue and the tentorium. Its path was chosen to avoid as far as possible destruction of brain tissue and

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SUMMARY

Stereotaxic methods with ventriculography, cisternography, angiography and phlebography in the postmortem examinations of posterior fossa displacements produced by experimental balloon tumours are described. Their application is discussed with special emphasis on angiography of the posterior fossa.

ZUSAMMENFASSUNG

Stereotaktische Methoden bei der Ventrikel- und Cisternenfullung und bei der postmortem Phlebographie nach kunstlich hervorgerufenen raumfordernden Prozessen werden beschrieben. Die erhaltenen Resultate werden hauptsachlich in Bezug auf die Angiographie der hinteren Schadelgrube bei solchen Prozessen kritisch besprochen.

RÉSUMÉ

Les auteurs decrivent les methodes stereotaxiques utilisant la ventriculographie, la cisternographie, l'angiographie et la phlebographie dans l'examen postmortem de deplacement dans la fosse posterieure produits par des ballons simulant experimentalement des tumeurs. Ils examinent l'application de ces methodes en particulier pour l'angiographie de la fosse posterieure.

REFERENCES

CORRALES M. and GREITZ T.: Fourth ventricle. II. Tumours of the cerebellum. Acta radiol. Diagnosis 12 (1972), 241.

DILENGE D. et DAVID M.: La branche meningée de l'artere vertebrale. Neurochirurgia (Stuttgart) 8 (1965), 121.

GALLOWAY J. R. and GREITZ T.: The medial and lateral choroid arteries. Acta radiol. 53 (1960), 353.

GIUDICELLI G. and SALAMON G.: The veins of the thalamus. Neuroradiology 1 (1970), 92.

GREITZ T. and SJÖGREN S. E.: The posterior inferior cerebellar artery. Acta radiol. Diagnosis 1 (1963), 284.

— and LAURÉN T.: Anterior meningeal branch of the vertebral artery. Acta radiol. Diagnosis 7 (1968), 219.

GREPE A.: The normal anatomy of the cerebellopontine angle as studied radiologically. *In* Nobel Symposium 10. Disorders of the skull base region. Almqvist & Wiksell, Stockholm 1969.

HAWKINS T. D. and MELCHER D. H.: A meningeal artery in the falx cerebelli. Clin. Radiol. 17 (1966), 377.

Results

Intracranial displacement of the ventricular system, the subarachnoid cisterns, the arteries and veins of the posterior fossa could be assessed with the procedures employed Despite the exact projections obtained with the stereotaxic method, it was frequently difficult to evaluate displacement of a minor degree, for which purpose the subtraction technique proved indispensable (Fig 2, 3, 4, 5) This more or less eliminated undisplaced structures, e g arteries and veins, while displaced structures appeared in white at their position before the displacement and in black after (or vice versa depending on the photocopying technique used) This facilitated not only the detection of any minor change in position but also its accurate recording These advantages were sometimes achieved at the expense of the comprehensiveness of the resultant subtraction film (Fig 5 c) The displacements had therefore to be examined with the aid of the non subtracted films as well (Fig 5 a, b)

Discussion

The stereotaxic method of postmortem angiography is of special interest in the investigation of vascular displacement in the posterior fossa Due to the tendency of the ventriculographic and pneumographic methods to produce herniations in intracranial expanding lesions, an increasing tendency has arisen during the last fifteen years to replace these methods with angiography This has been particularly true as regards supratentorial lesions As to expanding processes in the posterior fossa, the angiographic methods in many cases still fail to afford the surgeon sufficient information despite the fact that during the last decade many works have been published on the normal anatomy of the veins and arteries of the posterior fossa and the tentorial notch (GALLOWAY & GREITZ 1960, GREITZ & SJOGREN 1963, TAKAHASHI et coll 1967 1968, MANI et coll 1968 DILENGE & DAVID 1965, HAWKINS & MELCHER 1966, WOLF et coll 1962, 1963, HUANG et coll 1966, 1967, 1968, 1969, GIUDICELLI & SALAMON 1970) Several reasons for this failure probably exist, the rather abundant normal variations in the vascular anatomy of the posterior fossa may be one contributing factor The difficulty in obtaining a clinical material of expanding lesions that are well defined as to site and extension, is probably an important reason for the resources of technique and anatomic knowledge not having yet been fully exploited It therefore seems reasonable to assume that an experimental investigation with the technique described and the application of a well defined classification of localization (CORRALES & GREITZ 1972), should be a significant contribution in achieving the goal of making vertebral angiography as reliable an examination as carotid angiography is to-day

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ANOMALOUS ORIGINS OF THE SINUS NODE AND LEFT CIRCUMFLEX ARTERIES

Post mortem angiographic findings

by

J GARCES H ORTIZ and E STANISLAWSKY

The application of radiologic techniques corrosion methods and new means of dissection have led to a better knowledge of the coronary artery anatomy and pathology Postmortem angiographic investigations of these arteries were initiated by GROSS in 1923 since when the work in this field has been much improved especially by SCHLESINGER (1957) and FULTON (1965) Corrosion techniques were started by HYRTL (1855) and HENLE (1866) (quoted by SPALTEHOLZ 1924) who used low grade fusion metals to fill the coronary bed new materials such as nylon (WAGNER & POINDEXTER 1949) plexene or vinyl (JAMES & BURCH 1958 VINEBERG & MUNRO 1965) are now employed The specimens obtained through the corrosion techniques are useful specially for teaching

Individual films must be obtained of the atrium the ventricular walls and the interventricular septum Among the myocardium dissection techniques for the angiographic investigation of the coronary arteries those of SPALTEHOLZ (1924),

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HORNSTEIN R, LUNDH A and SJOGREN S E The subtraction method Acta radiol Diagnosis 2 (1964) 264

HUANG Y P and WOLF B S Precentral cerebellar vein in angiography Acta radiol Diagnosis 5 (1966) 250

— — The vein of the lateral recess of the fourth ventricle and its tributaries Amer J Roentgenol 101 (1967) 1

— — and OKUDERA T Angiographic anatomy of the inferior vermian vein of the cerebellum Acta radiol Diagnosis 9 (1969) 327

— — ANTIN S P and OKUDERA T The veins of the posterior fossa—anterior or petrosal draining group Amer J Roentgenol 104 (1968) 36

LEKSELL L A stereotaxic apparatus for intracerebral surgery Acta chir scand 99 (1949) 229

— The stereotaxic method and radiosurgery of the brain Acta chir scand 102 (1951) 316

— Some principles and technical aspects of stereotaxic surgery *In* Pain p 493 Little Brown and Company Boston 1966

LILIEQUIST B The subarachnoid cisterns An anatomic and roentgenologic study Acta radiol (1959) Suppl No 185

MANI R L NEWTON T H and GLICKMAN M G The superior cerebellar artery an anatomic roentgenographic correlation Radiology 91 (1968) 1102

MOLLER A Selective postmortem angiography of the posterior fossa Technical consideration Acta radiol Diagnosis 12 (1972) 401

NEWTON T H The anterior and posterior meningeal branches of the vertebral artery Radiology 91 (1968) 271

RUGGIERO G and MAZZACURATI M Subtraction technique in encephalography Preliminary report Invest Radiol 2 (1967) 326

— et DE TORRI P La soustraction d image en angiographie cérébrale bidirectionelle simultanée Delachaux et Niestlé Neuchatel 1967

TAKAHASHI M WILSON G and HANAFEE W The significance of the petrosal vein in the diagnosis of cerebellopontine angle tumors Radiology 89 (1967) 834

— — — The anterior inferior cerebellar artery Its radiographic anatomy and significance in the diagnosis of extra axial tumors of the posterior fossa Radiology 90 1968 281

WOLF B S NEWMAN C M and KHILNANI M T The posterior inferior cerebellar artery on vertebral angiography Amer J Roentgenol 87 (1962) 322

— HUANG Y P and NEWMAN C M The lateral anastomotic mesencephalic vein and other variations in drainage of the basal cerebral vein Amer J Roentgenol 89 (1963) 411

ZIEDSES DES PLANTES B G Subtraktion Fortschr Röntgenstr 52 (1935) 69

The heart having been removed, the coronary arteries were canalized and a barium sulfate emulsion injected (SCHLESINGER 1957). Stereoscopic films were taken with the immersion method (FULTON 1965). The myocardium was then unrolled (RODRIGUEZ & REINER) and further stereoscopic films obtained of the atrial wall, ventricular cone and apex. The results were compared with those of the segmentary atrial and ventricular angiographies.

Case reports

Case 1. The left circumflex artery in this case arose anomalously from the right coronary artery and ran behind the aortic trunk to reach the left arterial ventricular sulcus (Fig. 1); the anterior descending artery arose directly from the aorta (Fig. 1) and the sinus node artery arose from the left circumflex artery.

Case 2. The sinus node artery in this case arose as end artery from the right circumflex artery (Fig. 2) and reached the posterior wall of the atrial myocardium (Fig. 3). It should normally run to the anterior wall (Fig. 4).

Discussion

The anomalous origin of the sinus node artery in Case 2 appears to be unique. JAMES (1965), PAULIN (1964), SNELL (1966) and SMITH (1962) stated that this artery in 55 per cent of cases arises from the first few centimeters of the right coronary artery and in the remaining cases close to the origin of the left circumflex artery. The sinus node artery usually runs to the anterior wall of the atrium (Fig. 4).

The anomaly described in Case 1 is a recognized anatomic variant (DEMANN & ZIMMERMANN 1967; HALLAN & COOLEY 1966). The interest lies only in the fact that it formed an objective demonstration of an infrequent anatomic distribution of the coronary arteries.

SUMMARY

Two anatomic coronary artery variants in a material of 106 cases in which coronary angiography was performed post mortem are described. One of these anomalies has not been previously described.

ZUSAMMENFASSUNG

An einem Material von 106 postmortem Coronarangiographien konnten zwei Hauptvarianten der Coronararterien festgestellt werden. Eine dieser Varianten wurde bisher noch nicht beschrieben.

RÉSUMÉ

Description de deux variations anatomiques de l'artère coronaire sur un groupe de 106 cas examinés post mortem par angiographie coronaire. Une de ces anomalies n'a pas été décrite auparavant.

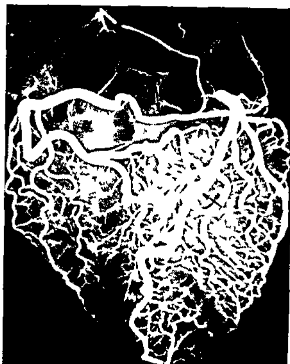


Fig 1 Case 1 The left circumflex artery (—→) arises from the right coronary artery (-+→) and the sinus node artery (↦→) from the left circumflex artery The anterior descending artery (>—→) is independent of the left circumflex artery (—→)



Fig 2 Case 2 The sinus node artery (↦→) forms the terminal part of the right circumflex artery (o→) Right coronary (-+→) anterior descending (↦→) arteries



Fig 3 Case 2 The sinus node artery (↦→) anomalously runs to the posterior wall of the atrium

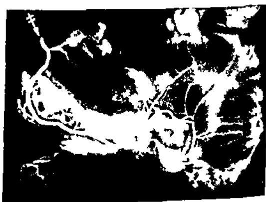


Fig 4 The sinus node artery (↦→) runs to the anterior wall of the atrium

Rodriguez & Reiner (1957) and Chen Chi San et coll (1966) should be mentioned as being the most important

Material and Methods The material consisted of 106 cases in which coronary angiography was performed post mortem

The heart having been removed, the coronary arteries were canalized and a barium sulfate emulsion injected (SCHLESINGER 1957) Stereoscopic films were taken with the immersion method (FULTON 1965) The myocardium was then unrolled (RODRIGUEZ & REINER) and further stereoscopic films obtained of the atrial wall ventricular cone and apex The results were compared with those of the segmentary atrial and ventricular angiographies

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REFERENCES

Blumgart H. K. Coronary arteries. Amer. J. Med. 5 (1948) 321.

Brower H. A. The normal and the pathological anatomy and histology of the arterial component of the coronary circulation system. Acta cardiol. (Brux.) 20 (1965), 218.

Chen Chi San, Ssut U, Tsai Hsiao and Han Yun Hua. A new method of dissection of the heart for coronary arteriography. Chin. med. J. 85 (1966), 326.

Demany M. and Zimmermann H. Congenital anomalies of the coronary arteries. Angiology 18 (1967) 270.

Fulton W. F. M. The coronary arteries. Published injection methods. Charles C Thomas, Springfield, Illinois 1965.

Gensini G. and Di Giorgi S. Anatomy of the coronary circulation in living man. Circulation 31 (1965) 778.

Gross L. The blood supply to the heart. Paul B. Hoeber, New York 1923.

Hallan G. L. and Cooley D. A. Congenital anomalies of the coronary arteries. Surgery 59 (1966) 133.

James N. T. Anatomy of the coronary arteries in health and disease. Circulation 32 (1965) 1020.

James T. N. and Burch G. E. The atrial coronary arteries in man. Circulation 17 (1958) 90.

Meng I. and Eckner F. Coronary artery distribution in tetralogy of Fallot. Arch. Surg. 90 (1965) 363.

Paulin S. Coronary angiography. A technical, anatomic and clinical study. Acta radiol. (1964) Suppl. No. 233.

Rodriguez F. L. and Reiner L. A new method of dissection of the heart. Amer. J. Path. 63 (1964) 160.

Schlesinger M. J. New radiopaque mass for vascular injection. Lab. Invest. 6 (1957) 1.

Snell W. Roentgenographic anatomy of human coronary arteries. Amer. J. Roentgenol. 97 (1966) 359.

Smith G. T. The anatomy of the coronary circulation. Amer. J. Cardiol. 9 (1962) 327.

Spalteholz W. Die Arterien der Herzwand. S. Hirzel, Leipzig 1924.

Vineberg A. and Munro D. D. Four years clinical experience with internal mammary arterial implantation. Thorac. Surg. 29 (1965) 1.

Wagner A. and Pindexter C. A. Demonstration of the coronary arteries with nylon. Amer. Heart J. 37 (1949) 258.

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LEFT VENTRICULAR CHANGES DURING CORONARY ARTERY OCCLUSION IN DOGS

by

N. E. AHLBERG, S. PAULIN and I. SEEMAN

The clinical signs of acute myocardial ischaemia are generally typical and may be revealed by changes in the electrocardiogram and enzyme levels in the blood. These changes are not, however, directly correlated to the impairment of the pumping action of the heart. Increasing interest has therefore been directed towards the contraction mechanism of the heart, and general principles have been evolved for muscle work performance in the analysis of left ventricular function (ROSS et coll. 1967). This necessitates detailed information about the anatomic changes during ventricular contraction under normal and abnormal circumstances, particularly during ischaemia.

Myographic investigations have revealed that when a coronary arterial branch is occluded, the contractility in the corresponding muscle area will rapidly diminish (TENNANT & WIGGERS 1935, FRONEK & PIŠA 1957, TATOOLES & RANDALL 1961). Such a decrease in contractility within an ischaemic area of the left ventricle ought to be accompanied by changes in ventricular movement and has been confirmed by cinematographic techniques (PRINZMETAL et coll. 1949, SAYEN et coll. 1958), roentgen kymography (SUSSMAN et coll. 1940) and electrokymography (DACK 1955, BARTLEY 1960, TUMANOVSKY et coll. 1961). The common denominator in these methods is, however, that they record changes in movement only at the cardiac surface and afford no information concerning

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REFERENCES

BLUMGART H K Coronary arteries Amer J Med 5 (1948) 321

BROWER H A The normal and the pathological anatomy and histology of the arterial component of the coronary circulation system Acta cardiol (Brux) 20 (1965), 218

CHEN CHI SAN, SSUT'U TSAI HSIAO and HAN YUN HUA A new method of dissection of the heart for coronary arteriography Chin med J 85 (1966) 326

DEMANY M and ZIMMERMANN H Congenital anomalies of the coronary arteries Angiology 18 (1967) 270

FULTON W F M The coronary arteries Published injection methods Charles C Thomas Springfield Illinois 1965

GENSINI G and DI GIORGI S Anatomy of the coronary circulation in living man Circulation 31 (1965), 778

GROSS L The blood supply to the heart Paul B Hoeber New York 1923

HALLMAN G L and COOLEY D A Congenital anomalies of the coronary arteries Surgery 59 (1966), 133

JAMES T N Anatomy of the coronary arteries in health and disease Circulation 32 (1965) 1020

JAMES T N and BURCH G E The atrial coronary arteries in man Circulation 17 (1958), 90

MENG L and ECKNER F Coronary artery distribution in tetralogy of Fallot Arch Surg 90 (1965) 363

PAULIN S Coronary angiography A technical anatomic and clinical study Acta radiol (1964) Suppl No 233

RODRIGUEZ F L and REINER L *A new method of dissection of the heart Amer J* Path 63 (1964) 160

SCHLESINGER M J New radiopaque mass for vascular injection Lab Invest 6 (1957), 1

SNELL W Roentgenographic anatomy of human coronary arteries Amer J Roentgenol 97 (1966) 359

SMITH C I The anatomy of the coronary circulation Amer J Cardiol 9 (1962) 327

SPALTEHOLZ W Die Arterien der Herzwand S Hirzel Leipzig 1924

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BROWER H A The normal and the pathological anatomy and histology of the arterial component of the coronary circulation system Acta cardiol (Brux) 20 (1965), 218

CHEN CHI SAN, SSUT U TSAI HSIAO and HAN YUN HUA A new method of dissection of the heart for coronary arteriography Chin med J 85 (1966) 326

DIMANT M and ZIMMERMANN H Congenital anomalies of the coronary arteries Angiology 18 (1967) 270

FULTON W F M The coronary arteries Published injection methods Charles C Thomas Springfield Illinois 1965

CASSINI C and DI GIORGI S Anatomy of the coronary circulation in living man Circulation 31 (1965) 778

GROSS L The blood supply to the heart Paul B Hoeber New York 1923

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SNETI W Roentgenographic anatomy of human coronary arteries Amer J Roentgenol 97 (1966) 359

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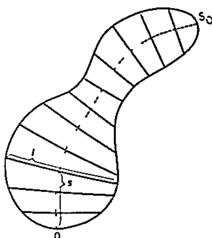


Fig 1 The mathematical model swept by a moving line (l) which varies as it moves with its centre along the left ventricular midline (0—S_0)

tion was therefore performed only in one projection in which the animals were placed on the left lateral side slightly tilted so that the area of the left ventricle marked by the metallic indicator was depicted tangentially Single roentgen films were also exposed in a horizontal projection with the position of the animal unchanged these controlled the cineangiographic projection being practically perpendicular to the long axis of the left ventricle Fixed tube film and object film distances were used in all experiments. The angiographies were performed with contrast medium injections either into the right or left atrium 25 ml contrast medium being injected into the right atrium and 10 ml into the left atrium The contrast medium (Isopaque Coronar) was injected with a power injector (Cisal I Elema Schonander) at a rate of about 15 ml per second ECG and blood pressures in the aorta left ventricle and right atrium were recorded simultaneously on a multichannel optical recorder (Elema Klinik) Mean pressures were obtained by electric integration

One to three temporary occlusions were performed on each animal and the effect on the myocardial wall was followed by five cineangiographic recordings The first recording was made before the coronary artery occlusion and the second and third were performed at 2 to 5 min and 10 min after the applied and still persisting effective occlusion The 10 min experimental occlusion having been removed the remaining recordings were performed 10 and 20 or 30 min later respectively The sequence of recordings was sometimes incomplete due to technical difficulties or the occurrence of terminal ventricular fibrillation after the release of occlusion The experimentally applied arterial occlusions were checked by the appearance of confirmatory changes in the ECG and their direct demonstration in selective coronary angiograms After the completed experiment

the whole ventricular wall Some authors have therefore used cineangiographic techniques for recording alterations in shape and movement of the left ventricular myocardium produced by coronary artery occlusion (HARLEY et coll 1968, PAIROLERO et coll 1970), these techniques appear to be suitable for this type of examination

Histology (BLUMGART et coll 1941, JENNINGS et coll 1960) has established that coronary artery occlusion for 20 minutes or less is unlikely to be associated with detectable changes in the myocardial cells, occlusions of 30 minutes or longer, however, nearly always result in cell damage, although functional alterations may appear after half a minute (LINDER & SEEMAN 1967, HARLEY et coll 1968) The muscle cells rapidly regain their normal function if the blood circulation has been restored after 1 up to 5 minutes of coronary artery occlusion (TENNANT & WIGGERS, TATOOLES & RANDALL, LINDER & SEEMAN) The effect of temporary occlusions of longer duration on functional development and reversibility of ischaemic muscle damage has however apparently not been investigated

Repeat cineangiography was used in dogs to indicate the development of changes in the left ventricular contraction movements during coronary artery occlusion of 10 minutes duration The recovery phase after such occlusion was then followed for 30 minutes

Material and Methods Fourteen mongrel dogs, weighing between 15 and 25 kg were anaesthetized with pentobarbital and curare, and ventilated with an O_2—NO_2 mixture in an Engstrom respirator Following exposure of the heart by left thoracotomy, a short section of the central branch of the left anterior descending coronary artery was dissected for later occlusion with a snare at a level that was expected to result in an ischaemic area corresponding to 25 per cent of the weight of the left ventricle (JOHANSSON et coll 1964, 1965, LINDER 1966) A metallic indicator was sutured to the epicardium in the middle of the ischaemic area to facilitate proper identification and positioning of the area in the radiographic recording system The pericardium and thorax were then closed and the occlusion snare was brought out through the thoracic wall The chest was then exsufflated The angiographic investigations were performed in direct sequence to operation A 35 mm Arriflex camera with cine pulse and a 9 inch image intensifier were used the films being exposed with a vertical roentgen beam direction at a speed of 65 frames/s The exposure data were 40 mA at 50 to 70 kV and the duration of each pulse was 3 ms A test run before these experiments indicated that the ischaemic changes were best evident in a projection in which the cineangiographic appearances of the left ventricle represented a plane through the center of the ischaemic area of the myocardium The angiographic examina



Fig 3 Cineangiography of the left ventricle in end diastole and end systole before (a) and during (b) occlusion of the left anterior descending coronary artery

The projection of the left ventricular cavity is regarded as a mathematical model A line called the left ventricular midline can be drawn from the base point to the apex (Fig 1) This line $(0—S_0)$ is formed by the middle point of a moving line (l) of variable length that sweeps over the geometric figure and is always perpendicular to the midline $(0—S_0)$ The moving line (l) however must not sweep over the same area twice (COURANT 1953) This mathematical model could be applied to all cineangiographic examinations of the left ventricle In

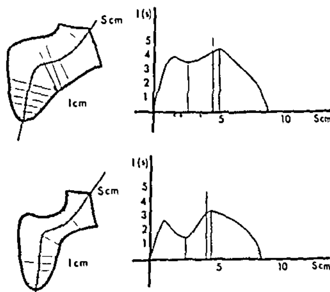


Fig. 2. The projected ventricular cavity and the corresponding image in the coordinate system in end diastole and end systole with the left ventricular midline and perpendicular diameters at 0.5 cm distance.

the animal was killed and the heart was excised. In none of the cases was hemorrhage or an increased accumulation of fluid observed in the pericardium. Injection of Keaton fast green (Ciba) was made into the anterior descending coronary artery to facilitate the delineation of the ischaemic part of the left ventricle. This part of the myocardium was cut out and weighed and its size expressed as a percentage of total left ventricular weight.

The cineangiograms were examined in a projector (Tagarno, Copenhagen) which permits frame by frame analysis up to a speed of 24 frames/s. The left ventricular cavity was examined directly on the projection screen for changes in shape and contraction during coronary artery occlusion. The contour of the contrast filled left ventricle was traced in all frames covering at least two complete heart cycles and from which end diastolic and end systolic frames were assessed. The end diastolic frame was chosen as the one that immediately preceded the closure of the mitral valve, whereas the frame exposed immediately before the closure of the aortic valve represented end systole. Closure of both aortic and mitral valves were easily identified in the cine films. The phases of the cardiac cycle were designated in accordance with the nomenclature of WIGGERS (1921). End diastolic and end systolic areas of the left ventricular cavity were determined planimetrically and the long axis of the left ventricular cavity was measured as the linear distance from the apex to the base, the latter identified as the junction between the aortic and mitral valves.

Considerable variations in the shape of the ventricular cavity were evident before and during occlusion, particularly in end systole. A special type of assessment was arranged to facilitate comparison between these different shapes

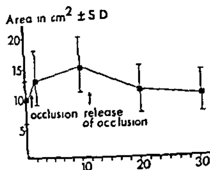


Fig 5 Variations in the projected area of the left ventricular cavity (mean±SD) in end systole before during and after occlusion of the left anterior descending coronary artery

descending coronary artery however the shape and contraction of the left ventricular cavity changed in a characteristic way (Figs 3 b, 4 b) The apical ventral part of the cavity remained distended during the isovolumetric contraction phase as well as during those of maximum and reduced ejection whereas the unaffected parts contracted normally The changes in shape gradually increased until a maximum was reached in end systole when the chamber became pear or club-shaped During the phase of isovolumetric relaxation and protodiastole these changes gradually disappeared during the later part of diastole the shape was indistinguishable from that present before the occlusion The changes described were consistently observed as early as two minutes after the start of occlusion and were accentuated only to a small degree during the following additional eight minutes of occlusion

Area length and diameters of the projected ventricular cavity in end systole and end diastole These parameters were investigated in 10 dogs. The ischaemic areas were estimated as 26 5 (SD 5 9) per cent of the total left ventricular weight The end systolic area of the left ventricular cavity increased significantly from 9 6 (SE 0 96)cm² before the coronary artery occlusion to 13 4 (SE 1 11) cm and 15 2 (SE 1 30)cm after 2 and 10 minutes duration of occlusion respectively (Fig 5) Ten minutes after release of the occlusion the end systolic area decreased significantly to 11 1 (SE 1 14)cm² and after 20 minutes the area was 10 5 (SE 1 18)cm In spite of the return to almost normal area values slight pear and club-shaped deformity of the chamber persisted in end systole for thirty minutes after the release of the occlusion

The end diastolic area of the cavity was 16 6 (SE 1 31)cm² determined before coronary artery occlusion and did not increase appreciably after two minutes of occlusion A significant increase of the area to 19 4 (SE 1 46)cm was however evident after ten minutes of occlusion after its release the area returned to the same value as before

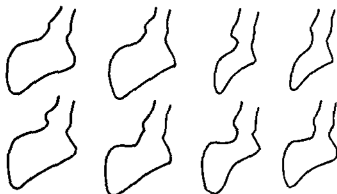


Fig. 4. Contour tracings of the contrast filled left ventricular cavity in different phases of the heart cycle before (a, top) and during (b, bottom) occlusion of the left anterior descending coronary artery.

some of the projections a short section of the midline is, however, not perpendicular to the moving line (l) if the area has not to be swept over twice. These deviations from the mathematical model are considered to be small and are neglected. The expression of the length of the moving line (l) as a function of the arc length (s) of the left ventricular midline in a coordinate system enables comparison of different shapes of the left ventricular cavity as well as the calculation of the apical and basal parts of the area of the cavity easily to be performed (Fig. 2). By definition of integral and area the left ventricular tracing area is equal to the area of the corresponding region in the coordinate system (COURANT). Moreover, the mean diameter of the apical half on this constructed figure, which included the damaged area, as well as of the basal half have been determined.

The outer contour of the anterior wall of the left ventricle was traced in all cine frames during one heart cycle and its shape and position compared before and during coronary artery occlusion. An analysis of changes in thickness of the anterior left ventricular wall corresponding to the ischaemic area was performed by measuring the distance between the epicardium and the endocardium of the left ventricle from all traces obtained in one complete heart cycle.

Correction for magnification was accomplished by a fine meshed metal grid placed at the same distance as the left ventricle from the image intensifier input and recorded in the cine films. The correction factor was 0.755. Distortion of the test square net in the periphery of the intensifier image was small and therefore not compensated for in the measurements.

Results

Shape and movement of the ventricle during different phases of the heart cycle. The left ventricle before coronary artery occlusion contracted and dilated symmetrically (Figs. 3 a, 4 a); during occlusion of a branch of the anterior

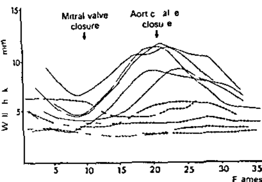


Fig 6 Changes in thickness of the ventral part of the left ventricular wall corresponding to the myocardial ischaemia before (——) and during ( ) occlusion of the left anterior descending coronary artery

6 dogs failed to reveal either in end systole or in end-diastole the changes in shape and movement that were demonstrated on its inner contour The outer contour of the experimentally involved ischaemic area in all the experiments had the same shape as before occlusion whereas its inward—outward movement was decreased or sometimes abolished during occlusion No paradoxical movements could however be demonstrated

Before occlusion the thickness of the anterior ventricular wall varied considerably during the heart cycle It increased successively during systole to a maximum in end systole and decreased during diastole to a minimum in end diastole (Fig 6) The difference in the wall thickness in 5 dogs examined between these two phases was 6 (7 to 5)mm During occlusion however the anterior ischaemic wall in 2 dogs retained the end-diastolic dimension during the complete heart cycle and in 2 other dogs the wall thickness in end systole was 3 mm less than in end diastole (Fig 6) the decrease in wall thickness in these 2 dogs occurred during isovolumetric contraction and the increase was limited to the isovolumetric relaxation A slight increase however in wall thickness occurred during systole in the remaining dog

Discussion

Cineangiography was employed in the investigation as apart from giving some idea of the shape and contraction of the ventricular wall it presents a general conception of the ventricular cavity As in all angiographic methods objections may be raised to the uncertainty about the effect of the sudden injection of contrast medium the medium itself or the varying degrees of filling of the ventricular cavity The present conclusions have however been extracted from investigations on the same dog before and during coronary occlusions with

Table 1

Area of the ventricular images before and during coronary occlusion

	n	Total area	Apical area	Basal area
In end systole				
Before coronary occlusion in cm² ± SE	10	11.0 ± 1.18	4.8 ± 0.61	6.1 ± 0.[illegible]8
During coronary occlusion in cm² ± SE	10	15.9 ± 1.[illegible]0	8.3 ± 0.6[illegible]	7.7 ± 0.58
Difference in % ± SE	10	49.4 ± 6.33	83.[illegible] ± 11.60	[illegible]6.1 ± 6.71
In end diastole				
Before coronary occlusion in cm² ± SE	10	18.4 ± 1.39	8.4 ± 0.64	10.0 ± 0.77
During coronary occlusion in cm² ± SE	10	20.0 ± 1.19	9.3 ± 0.57	10.7 ± 0.6[illegible]
Difference in % ± SE	10	9.9 ± 3.46	12.3 ± 2.62	8.7 ± 4.31

Table 2

Mean diameter of the apical and basal parts of the ventricular images before and during coronary occlusion

	n	Apical diameter	Basal diameter
In end systole			
Before coronary occlusion in cm ± SE	10	1.6 ± 0.16	2.0 ± 0.14
During coronary occlusion in cm ± SE	10	[illegible].3 ± 0.14	2.[illegible] ± 0.19
Difference in % ± SE	10	56.2 ± 8.0	8.[illegible] ± 5.0
In end diastole			
Before coronary occlusion in cm ± SE	10	2.4 ± 0.11	2.9 ± 0.13
During coronary occlusion in cm ± SE	10	[illegible].6 ± 0.10	3.0 ± 0.1[illegible]
Difference in % ± SE	10	8.7 ± [illegible].0	4.7 ± 1.[illegible]

The figure drawn in the coordinate system indicated that the increase in end systolic area of the cavity following occlusion occurred mainly in the apical part (Table 1), this part increased by 84 per cent whereas the basal part increased by 26 per cent only. In end diastole, however, no difference in increase of areas was evident between the apical and the basal parts.

The mean apical diameter of the cavity increased during end systole with coronary artery occlusion by 56 per cent as compared with its preocclusion value, whereas the mean basal diameter increased by 8 per cent only (Table 2). The corresponding values for end diastolic mean diameters were 9 and 5 per cent respectively. The length of the cavity in end systole increased significantly from 5.9 (SE 0.16) cm to 6.6 (SE 0.13) cm during occlusion. The corresponding values in end diastole were 6.6 (SE 0.23) cm and 6.8 (SE 0.18) cm.

Changes in outer contour and wall thickness of the left ventricle. The outer contour of the ischaemic area of the anterior left ventricular wall examined in

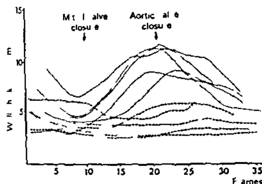


Fig 6 Changes in thickness of the ventral part of the left ventricular wall corresponding to the myocardial ischaemia before (——) and during ( ) occlusion of the left anterior descending coronary artery

6 dogs failed to reveal either in end systole or in end diastole the changes in shape and movement that were demonstrated on its inner contour The outer contour of the experimentally involved ischaemic area in all the experiments had the same shape as before occlusion whereas its inward—outward movement was decreased or sometimes abolished during occlusion No paradoxical movements could however be demonstrated

Before occlusion the thickness of the anterior ventricular wall varied considerably during the heart cycle It increased successively during systole to a maximum in end systole and decreased during diastole to a minimum in end-diastole (Fig 6) The difference in the wall thickness in 5 dogs examined between these two phases was 6 (7 to 5) mm During occlusion however, the anterior ischaemic wall in 2 dogs retained the end-diastolic dimension during the complete heart cycle and in 2 other dogs the wall thickness in end systole was 3 mm less than in end diastole (Fig 6) the decrease in wall thickness in these 2 dogs occurred during isovolumetric contraction and the increase was limited to the isovolumetric relaxation A slight increase however in wall thickness occurred during systole in the remaining dog

Discussion

Cineangiography was employed in the investigation as apart from giving some idea of the shape and contraction of the ventricular wall it presents a general conception of the ventricular cavity As in all angiographic methods, objections may be raised to the uncertainty about the effect of the sudden injection of contrast medium the medium itself or the varying degrees of filling of the ventricular cavity The present conclusions have however been extracted from investigations on the same dog before and during coronary occlusions with

the same injection technique, the error must therefore be inherent in all the examinations performed.

Acute occlusion of a coronary artery implies a marked reduction of blood flow in the corresponding vascular segment of the myocardium. The myocardial cells in the region will then be supplied mainly from collateral blood vessels (GREGG & FISCHER 1963). Since the magnitude of this flow in the acute stage is not sufficient, impairment of myocardial contractility rapidly follows (TENNANT & WIGGERS 1935). This phenomenon is responsible for the changes in shape and contraction of the ventricle demonstrated in this investigation by acute coronary occlusion. The club- or pear shape of the ventricular cavity in systole and the absence of variations in wall thickness in the ischaemic wall during the heart cycle must be due to the fact that some part of the muscle wall loses the power of contractility. Thus, cineangiographic demonstration of the effect of local ischaemia apparently is possible immediately after the onset of coronary occlusion. The question, however, arises as to how these changes influence ventricular function and to what extent cineangiography may contribute to the detection of such an influence on the ventricular performance. Theoretically, these changes in shape may be expected if the ischaemic muscle cell loses so much contractile power that it becomes stretched during isovolumetric contraction, remains stretched during the rest of systole, and shortens during isovolumetric relaxation (TENNANT & WIGGERS) or if the ischaemic cells remain passively stretched in end diastolic length during the heart cycle. It is conceivable that at times some layers of the wall in the ischaemic region may remain intact with normal contractility which would explain the different results of measurements of the wall thickness, demonstrated in the present investigation.

The shape and contraction of the outer contour of the myocardial wall without paradoxical movements during ischaemia strongly indicate that a direct outward bulging of the ischaemic myocardial wall is absent. These findings are contrary to the observations made by PRINZMETAL et coll. (1949) who reported that the ischaemic part of the heart wall had a systolic bulging during temporary occlusion. It may, however, be argued that the latter investigation was made with an open chest and pericardium; possibly the tight pericardium will normally prevent local outward movements of the myocardial wall (FERGUSON et coll. 1953). On the other hand, paradoxical movements of the outer contour corresponding to ischaemic regions have been demonstrated by electrokymographic technique in clinical practice (DACK 1955, BARTLEY 1960). These movements are, however, registered from several days up to several weeks after acute myocardial infarction and the results are therefore difficult to compare with the present results.

It is obvious, however, that regardless of the explanation offered of the altered mode of movement of the wall the area of the ventricle in end systole is larger

during coronary occlusion This enlargement will be derived essentially from that part of the cavity corresponding to the ischaemic wall region Functionally, this must mean an increased residual blood volume in end systole The end diastolic area of the ventricle will also increase but more as a general dilatation

This reserve capacity of the heart to compensate for the dysfunctioning muscle cells may explain the relatively small haemodynamic changes following acute coronary occlusion (RUSHMER 1969) Due to this the cineangiographic technique therefore seems to afford an opportunity to demonstrate the functional disturbances that follow myocardial ischaemia

Acute myocardial ischaemia cannot be expected to produce completely pathognomonic changes in the ventricle due to the varying structure of the coronary artery system (BAROLDI et coll 1956, FULTON 1965) The loss of contractility of the myocardial cells during the ischaemia is however, so uniform that acute occlusion of different coronary artery branches ought to produce more or less the same changes in shape and contraction of the ventricular wall This is supported by the fact that the local changes in the dorsal aspect of the left ventricle during acute occlusion of the circumflex coronary artery in dogs (HARLEY et coll 1968) are similar to those in the apico-ventral part of the ventricle now described

The myocardial cells seem to be sensitive to changes in vascular supply as ischaemia is followed by impaired muscular function as early as the first two minutes after coronary artery occlusion This is in agreement with previous investigations (TENNANT & WIGGERS 1935 TATOOLES & RANDALL 1961 LINDER & SEEMAN 1967) Temporary occlusions of short duration do not result in persistent myocardial cell damage (BLUMGART et coll 1941 JENNINGS et coll 1960) but the functional changes returned remarkably slowly and were still detectable in this investigation 30 minutes after the release of the ten minute occlusion This occurred in spite of the fact that marked electrocardiographic changes had disappeared and the selective coronary angiogram indicated complete patency immediately after the release of the occlusion In addition examinations of the coronary blood flow after short temporary occlusions have established that the coronary flow returns to normal practically immediately in the ischaemic area (LINDER 1966)

Acute coronary artery occlusion is followed by a changed blood supply with gradually increasing passage through the collateral pathways (FULTON 1965 SCHAPER 1967 RUSSEL REEZE & REDDING 1967) Different parts of the myocardium thus receive a different blood supply so that some muscle cells in the area of the occluded artery survive while others undergo necrosis and are replaced by fibrotic tissue On account of this the changes in the left ventricle demonstrated in the present investigation are unlikely to remain unaltered during

restitution, in fact some regression of the ischemic changes of the ventricle has also appeared between the first and fourth weeks after occlusion (PAIROLERO et coll 1970) although about 50 per cent of the changes persisted for at least three months

Cineangiography of the left ventricle thus appears to be a sensitive means of detecting local functional abnormalities of the myocardium during, as well as after temporary coronary occlusion These changes present a local bulge of some part of the cavity and an absence in the normally occurring increase in wall thickness during systole The resulting change in the shape of the left ventricle is likely to be of significant functional importance The occurrence of local dilatation of the ventricular lumen during systole must imply a deteriorated pumping function of the ventricle with increased end systolic blood volume, whereas the nature of the general increase in the left ventricular cavity in end diastole may represent an adaptive mechanism to maintain its work load The influence of the contrast medium on myocardial function when injected repeatedly in the experiments cannot be assessed This should however involve the myocardium in toto and therefore not influence the observations made concerning localized abnormalities in myocardial function

Cineangiography to map the projected ventricular lumen during the different phases of the heart cycle and register multiple parameters seems to offer essential possibilities for analysis of functional changes in the left ventricle during local myocardial damage

Acknowledgement

This investigation was supported by grants from the Swedish National Association against Heart and Lung Diseases the Swedish Medical Research Council (Project No B70 14X 2726 02B) the Swedish Association for Medical Research and from the Faculty of Medicine University of Gothenburg

SUMMARY

The left ventricle was examined by cineangiography during temporary occlusion of the left anterior descending coronary artery in dogs Changes in shape and contraction of the chamber and outer contour of the ventricle together with the wall thickness were registered during the same procedure Certain parameters estimated in end systole and end diastole before and during occlusion are discussed

ZUSAMMENFASSUNG

Der linke Ventrikel wurde cineangiographisch während eines temporären Verschlusses der linken absteigenden Koronararterie an Hunden untersucht Die Änderungen der Form und der Kontraktion der Kammer und die aussere Kontur des Ventrikels zusammen mit der Dicke der Wand wurden gleichzeitig registriert Gewisse Parameter die in der End Systole und End Diastole vor und wahrend des Verschlusses bestimmt wurden werden diskutiert

RÉSUMÉ

Le ventricule gauche a ete examine sur des chiens par une angiographie au cours d une obstruction temporaire de l artere coronaire descendante anterieure gauche Les modifications de forme et la contraction de la chambre et du contour externe du ventricule ainsi que l epaisseur de la paroi on ete enregistres au cours de ce meme examen Les auteurs examinent certains parametres estimes a la fin de la systole et a la fin de la diastole avant et pendant l obstruction arterielle

REFERENCES

BAROLDI G MANTERO O and SCOMAZZONI G The collaterals of the coronary arteries in normal and pathologic hearts Circulat Res 4 (1956) 223

BARTLEY O Electrokymographic changes in myocardial infarction Acta radiol 54 (1960) 81

BLUMGART H GILLIGAN R and SCHLESINGER M Experimental studies on the effect of temporary occlusion of coronary arteries Amer Heart J 22 (1941) 374

COURANT R Differential and integral calcules p 294 Blackie & Son London 1953

DACK S The ventricular pulsations in myocardial infarction a fluoroscopic and kymographic study Dis Chest 27 (1955) 282

FERGUSON T B SHADLE O W and GREGG D E Effect of blood and saline infusion on ventricular end-diastole pressure stroke work stroke volume and cardiac output in open and closed chest dog Circulat Res 1 (1953) 62

FRONEK A und ILLA Z Über die Blutdrucksenkung bei der akuten Ischamie des Myokards Arch Kreisl Forsch 27 (1957) 34

FULTON W F M The coronary arteries Charles C Thomas Springfield Illinois 1965

GREGG D E and FISCHER L C Blood supply to the heart *In* Handbook of physiology Section II p 1517 Edited by W F Hamilton Williams & Wilkins Baltimore 1963

HARLEY A BEHAR V and McINTOSCH H Immediate hemodynamic effects of acute coronary occlusion and their modification by anesthesia Amer J Cardiol 22 (1968) 559

JENNINGS R SOMMERS H and SMYTH G et coll Myocardial necrosis induced by temporary occlusion of a coronary artery in the dog Arch Path 70 (1960) 8?

JOHANSSON B LINDER E and SEEMAN T Collateral blood flow in the myocardium of dogs measured with Krypton Acta physiol scand 62 (1964) 263

— — — Coronary collateral blood flow in relation to the mass of ischemic myocardium studied with Krypton Acta physiol scand 63 (1965) 495

LINDER E Measurements of normal and collateral coronary blood flow by close arterial and intramyocardial injection of Krypton and Xenon[133] Acta physiol scand (1966) Suppl No 272 p 5

— and SEEMAN T Effects of persantin and nitroglycerin on myocardial blood flow during temporary coronary occlusions in dogs Angiologica 4 (1967) 225

PAIROLERO P HALLERMAN F and ELLIS H The left ventriculogram in experimental myocardial infarction Radiology 95 (1970) 311

PRINZMETAL M SCHWARTZ L and CORDAY E et coll Studies on the coronary circulation VI Loss of myocardial contractility after coronary artery occlusion Ann intern Med 31 (1949) 429

ROSS J COVELL J and SONNENBLICK E The mechanics of left ventricular contraction in acute experimental cardiac failure J clin Invest 46 (1967) 299

RUSHMER R Function of infarcting myocardium Circulation (1969) Suppl No 4, p 168

RUSSEL REEZE J and REDDING V J Effects of dipyridamole on anastomotic blood flow in experimental myocardial infarction Cardiovasc Res 1 (1967) 179

SAYEN J, SHELDON W PEIRCE G and KUO P Polarographic oxygen the epicardial electrocardiogram and muscle contraction in experimental acute regional ischemia of the left ventricle Circulat Res 6 (1958) 779

SCHAPER W The collateral circulation in the canine coronary system Thesis Faculty of Medicine University of Louvain 1967

SUSSMAN M, DACK S and MASTER A The roentgenkymogram in myocardial infarction Amer Heart J 19 (1940) 453

TATOOLES C and RANDALL W Local ventricular bulging after acute coronary occlusion Amer J Physiol 201 (1961) 451

TENNANT R and WIGGERS C The effect of coronary occlusion on myocardial contraction Amer J Physiol 112 (1935) 351

TUMANOVSKY M N HARMACH V Ya and NOVIKOV Yu G Electrokymographic study of the dog s heart under normal conditions and after experimentally induced myocardial infarction Ter Arkh 33 (1961) 11

WIGGERS C J Studies on the consecutive phases of the cardiac cycle I The duration of the consecutive phases of the cardiac cycle and the criteria for their precise determination Amer J Physiol 56 (1921) 415

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SIGNIFICANCE OF ALTERATIONS IN MAIN RENAL ARTERY CALIBRE AND CONFIGURATION

by

H LUDIN E J JUBIN H J KAUFMANN and W VON PEIN

Renal artery stenosis and occlusion as a cause of potentially curable arterial hypertension have been the subject of numerous investigations Other changes in the extrarenal part of the renal arteries such as a decrease in calibre or tapering of these vessels in a distal direction have received comparatively little attention

THOMA (1893) observed that the calibre of blood vessels appears to vary with the local blood flow Investigations of renal arteries have revealed a correlation between the renal area as determined from roentgenograms obtained by the ellipsoid surface formula (MOELL 1956 LUDIN 1961), kidney weight at autopsy and renal plasma flow estimated from the PAH clearance or renal blood flow (Table 1) Correlation 1 (Table 1) agrees largely with the investigation of KITTREDGE et coll (1964) The size of the variance about the regression line in correlation 1 (Table 1) may in part be due to a variable discrepancy between the renal plasma flow and renal blood flow It has not been possible to estimate the magnitude of the latter since neither haematocrit values nor the extraction ratio were determined It is however, noteworthy

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Table 1

Investigations correlating 'renal area', kidney weight, renal artery cross sectional area, renal plasma flow and renal blood flow in healthy and diseased kidneys

Author	Correlation	Correlation between (y)	and	(x)	Correlation coefficient r	Estimated fraction of y depending on x: r^2
(1) Ludin (1965) (a) Ludin et coll. (1967) (a)	Linear	Renal plasma flow (PAH clearance)		Renal artery cross sectional area	0.783	[illegible] per cent
(2) Olstad et coll. (1969) (a)	Non linear (?)			Renal artery diameter	0.81	65 per cent
(3) Olstad et coll. (1969) (a)	Non linear (?)			Renal artery cross sectional area	0.72	[illegible] per cent
(4) Ludin (1965) (a) Ludin et coll. (1967) (a)	Linear	Renal artery cross sectional area		Kidney area (b)	0.671	46 per cent
(5) Wojtowicz (1967) (c)	Non linear				0.77	59 per cent
(6) Ludin (1967) (d)	Non linear	Renal weight			0.952	90 per cent

(a) Clinical material: most kidneys diseased
(b) Method of Moell (1956)
(c) Normal single kidneys
(d) Correlation investigation between radiographic measurements and weight values from autopsy

that using a direct dye dilution method (Olin 1971) the variance about the regression line does not differ appreciably from correlation 1 (Table 1).

Mainly due to autoregulation, renal blood flow is known to vary appreciably from one period to another (Reubi 1970). Olin reported the correlation between renal blood flow and renal artery size to be closer in nephrosclerosis than in any other condition. This observation might be explained by an increased stiffness of the arteriolar walls resulting in a limitation of the autoregulatory function. The blood flow in arteriolar nephrosclerosis would thus vary less under changing conditions.

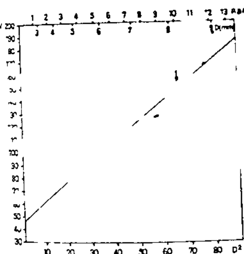


Fig 1 Regression of renal weight (g) W estimated nomographically from renal area in WOJTOVICZ material on square of renal artery diameter (mm) D Arro Renal blood flow (ml s) corresponding to kidney weight of 150 g estimated according to FONTAINE et coll has a value of about 10 ml s (SD about 20 per cent) RBF values roughly corresponding to arterial diameters indicated on top

It seems reasonable however in agreement with THOMA s concept to assume that the average renal blood flow is in a linear relation with the mass or weight of potentially functioning renal parenchyma In WOJTOVICZ material (regression 5 Table 1) renal weight values W were therefore estimated from his renal area figures A by the formula $W = 0\,62449 \times A^{1\,3}$ (LUDIN 1967 cf correlation 6 Table 1 and Fig 4) Correlating these weight values with the square of the renal artery calibre resulted in a near linear regression (Fig 1) The diagram indicates that an optimum curve fit would probably have been obtained with OLIN s function RBF α $A^{1\,5}$ rather than the quadratic expression RBF α 1 of our data This might possibly be due to the relative proportions of cortical and medullary blood flow

The weight of normal kidneys bears a near linear correlation both with the square of the renal artery calibre and the renal blood flow The latter relation was investigated by several workers the following values being given in terms of millilitres RBF per gram kidney per minute FONTAINE et coll (1969) 3 8±0 78 (dogs) THURAU (1964) 4 to 5 (animal experiments) KRAMER & DEETJEN (1964) 4 02 The corresponding figure for a healthy human kidney weighing 150 g would thus be about 600 ml/min or 10 ml/s Based on these values an attempt was made to calculate a rough estimate of renal blood flow from renal artery calibre (Fig 1) These figures would evidently require further confirmation by direct measurement (OLIN)

Any hypothesis concerning the mechanism of adaptation of arterial calibre to local blood flow must for the time being remain speculative RODBARD et coll

(1967) in investigating the pathogenesis of post stenotic dilatations assumed that the arterial calibre adapts itself to long term changes in the local blood flow by anatomic reorganisation of the mural tissues, the stimulus for maintaining or changing the calibre is postulated to be the average shearing stress exerted by the moving blood column upon the intimal layer.

Provided a mechanism adapting arterial calibre to local blood flow exists, the feed back signal most probably arises from the intimal layer. Increased blood pressure per se does not appreciably deform the endothelial cells, any deformation being produced by the shearing stress mentioned (FRY 1968). The shearing stress within major or medium sized arteries is small, at the arteriolar level, however, this stress stems from the axial pressure gradient and the vascular cross-sectional area (LUDIN 1964). The gradient is increased in systemic or pulmonary hypertension. The arteriolar cross sectional area may be increased in order to (1) allow for a greater than normal local blood flow in pulmonary hypercirculation due to left to right shunt, eventually associated with pulmonary hypertension or (2) compensate for a loss of a proportion of the arteriolar bed caused e.g. by a numerical reduction in the functional units as occurs in pulmonary emphysema or pyelonephritis (LUDIN 1964). In view of the experimental results of FRY (1968) this mechanism might throw some light on the mechanical factors involved in the pathogenesis of pulmonary and systemic arteriolosclerosis, arteriolonecrosis, or both.

An attempt may be made to quantitate the hypothesis of RODBARD et coll. mentioned above. Although any mathematical description of pulsating blood flow in arteries in terms of steady flow, e.g. the application of Poiseuille's formula, is open to objection, a knowledge of instantaneous blood values may not be necessary in elaborating an approximate solution to the problem of relating mean flow over a longer period of time, Q (ml/s), to the average arterial calibre, D (cm). Thus if F/L be the shearing force (dynes per cm) exerted by a moving fluid column on the wall of a cylindric tube of length L (cm), Δp the pressure gradient (dynes per cm) between zero and L, μ the viscosity of the fluid (poise), from the well known formulas

$$F = -(\pi/4)\ D \quad \Delta p \text{ and } \Delta p = (128/\pi)\ Q\ L\mu/D^4$$

it follows that

$$F/L = -32\mu \quad Q/D^3 \tag{1}$$

If F/L be the critical shearing force at which average blood flow and arterial calibre are at equilibrium, then

$$Q \propto D\ , \tag{2}$$

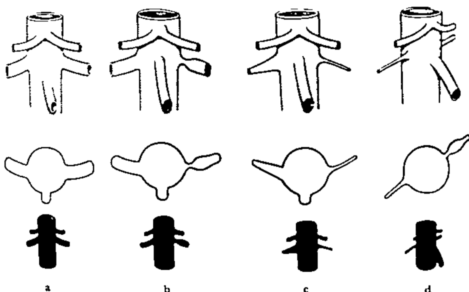
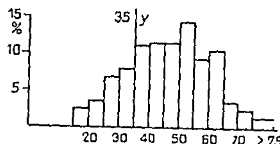


Fig 2 A rt c origin of s ngle renal a t ies Top Frontal ew M ddle Transverse section Bottom Aort graph c v ew a p a) Norm l ca b) Arte oscle ot c ten sis with post ten tic dilatation c) Right side Tapering renal t ry Left de Funn l haped origin of narrow renal artery d) Ax otation of ac rta due to arter o cler t c elong t on Rigl t side Funnel haped renal art ry origin Left side A terial steno s The chang s on both sides may be obscured by the contrast filled aorta and the oblique project on

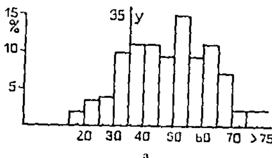
varying within relatively narrow limits Formula (2) relates flow to the diameter as a quadratic function in agreement with the near quadratic relation of renal weight to arterial calibre (cf Fig 1) A further support for this concept is gained from a comparison of the calibre of various healthy arteries supplying healthy organs perfused at a more or less constant rate, such as the kidney, liver, brain with an average local blood flow

Alterations of arterial calibre in disease due to lasting changes in local blood flow are a familiar finding in angiography Thus in arteriovenous fistula the arterial afferents are dilated in left to-right shunt the pulmonary arteries in chronic bronchitis the bronchial arteries in cirrhosis or abundant hypervascular metastases to the liver the hepatic artery in pregnancy the uterine vessels, in extrarenal retroperitoneal extension of renal carcinoma the lumbar arteries Examples of narrow arteries occur in hypoplastic limbs pulmonary stenosis abdominal aortic coarctation Similarly in investigation (4) mentioned in Table 1 16 of the 42 patients had to be excluded since it was soon apparent that in pyelonephritis the renal arteries tend to be appreciably narrow in relation to renal size particularly when the kidneys have not become markedly shrunken





b



a

Fig. 3. Age and sex distribution of a) 458 adults (278 males top and 180 females bottom) and b) 127 children (dotted bars refer to males and unfilled bars to females).

(LUDIN 1965 a). Shrinking indicates a significant decrease in renal blood flow due to loss of functioning parenchyma, i.e. a reduction in the perfusion/weight ratio of the kidney. Quantitatively, this may be expressed as a change in the value of a parameter $B = A^2/W$, the ratio between the square of the renal artery diameter, A, and the estimated renal weight, W, determined nomographically from the radiographic length and width of the kidney (LUDIN 1967, see below).

Certain animal experiments (IDBOHRN & MUREN 1956, IDBOHRN 1956, WIDEN 1958, THURAU 1964) demonstrated clearly the progressive adaptation of the renal blood flow and arterial calibre to the experimental reduction in the functioning renal parenchyma following unilateral ureteric ligation. Although during the first few minutes after occlusion the renal blood flow remains unchanged (THURAU), perfusion is decreased to about 50 per cent of the contralateral kidney within one week and to 23 to 50 per cent of the ipsilateral pre-occlusion rate at longer time intervals (IDBOHRN & MUREN). Angiography at corresponding intervals disclosed a reduction in calibre of the proximal and distal parts of the ipsilateral renal artery to about two thirds of the original values. The reduction progresses rapidly the first few weeks and ceases about two to three months following the ureteric ligation (IDBOHRN 1956, WIDEN 1958). Equation (2) reveals that the reduction in blood flow amounts to about the square of the calibre decrease. A decrease in renal artery calibre in pyelonephritis, glomerulonephritis, nephrosclerosis, hydronephrosis, tuberculosis or polycystic disease has also been observed, e.g. by IDBOHRN (1951), KITTREDGE

et coll (1964), FRIEDENBERG et coll (1965) HODSON (1967 a) and OFSTAD et coll (1969)

Attention was previously paid when measuring the calibre of renal arteries (LUDIN 1965) to the fact that the renal arteries often taper considerably from their origin to their first bifurcation Similar observations have been reported by IDBOHRN (1954) EDSMAN (1957) OLSSON & LUNDERQUIST (1963) FRIEDENBERG et coll (1965) and ELKIN et coll (1966) The decrease in calibre is either gradual or limited to the part near the aortic origin where it is marked (Fig 2) so that the vessel resembles a trumpet shaped funnel this was observed in some of the animal experiments mentioned It is felt that in the past some workers may have failed to distinguish this appearance from renal artery stenosis At the time of the previous investigation (LUDIN 1965) it was thought probable that such tapering is the consequence of a decrease of arterial calibre in a vessel that previously had been larger than at the time of aortography A similar concept has been proferred by PORSTMANN (1970)

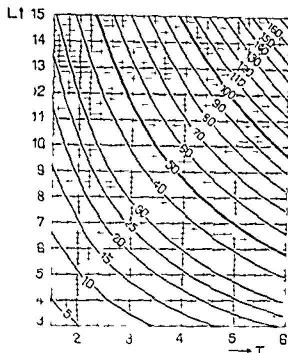
The significance of alterations in renal artery calibre and the various forms of arterial tapering prompted an investigation into a variety of pathologic conditions The calibre was comparatively easy to measure but accurate information about the actual state of the kidney was inevitably limited by the clinical variations so that the end results were appreciably affected

Material

Adult Nephroangiography was carried out on 615 patients during the period 1959—69 A total of 157 of these were excluded for the following reasons (1) Out patients because the controls were inadequate (2) selective arteriograms because they did not consistently demonstrate the proximal renal artery (3) incomplete examinations and (4) ectopic kidneys The age and sex distribution of the remaining 458 patients appear in Fig 3 a The ratio of patients below 56 years of age is virtually the same in either sex

Children A total of 144 out of 164 abdominal catheter aortographies performed during the period 1962—69 were available for review Twenty-one patients were excluded from the series for the same reason as in the adult material leaving 127 patients together with 4 paediatric patients from the adult material (Fig 3 b)

Autopsy The abdominal aorta of 27 bodies with parts of the renal arteries several centimetres in length were excised Two of these were from patients under 30 years of age with normal kidneys The remainder had abnormal kidneys 4 of the patients were 30 to 50 and the rest over 50 years at the time of death



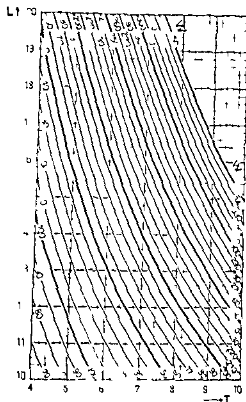


Fig. 1. Nomograms for estimating the weight of single kidneys (curves) from their radiographic length *L* and width *T* as measured in urograms or angiograms computed from the formula W = 0.491 (L · T)^1.14. Left: Small kidneys. Right: Normal sized or enlarged kidneys (LUDIN 1967.)

Methods

Aortography

Urografin 76 % was injected through a transfemoral catheter during the Valsalva manoeuvre. The resulting hypotension narrows the aorta but in the renal arteries a calibre reduction has never been observed, even in young subjects (LUDIN 1966).

The renal artery orifices are sometimes situated somewhere on the ventral or dorsal circumference of the aorta rather than on its true lateral aspect. This may be due either to anatomic variation or axial torsion of the abdominal aorta secondary to arteriosclerosis. This was overcome when the renal artery orifice was not clearly demonstrated in the last third of the adult series with another set of films exposed with the patient turned obliquely to an angle estimated from the initial course of the superior mesenteric artery. This second series usually defined the origin of the renal artery and indicated any abnormality of the proximal main vessel (Fig. 2). Two arteries supplying the same kidney

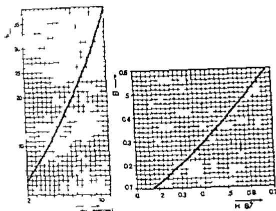


Fig 5 Calculation of the parameter B from the length L and width T (cm) of single kidneys and the calibre of the renal artery A (ml) Left The values of G are given as a function of A and from these L and T H is calculated from the formula $H = G/(0.531 \times L \times T)$ Right B as a function of H

occasionally arise from the aorta at the same level and become superimposed in the films. This may simulate proximal branching of a narrow renal artery

The evaluation of films included the following observations relating to the renal arteries (1) The number supplying each kidney (2) the shape of their orifices (Fig 2) (3) their calibre at 1 and 3 cm from their origin (4) any bifurcation less than 3 5 cm from their origin and (5) the length and width of the kidneys measured in the nephrographic phase about seven seconds after the Valsalva manoeuvre was discontinued

From these data the following arterial parameters were calculated for statistical analysis

The diameter of single renal arteries at about 3 cm from their origin A This is probably a better reflection of renal blood flow than the average of calibre values measured at 1 1 5 and 2 cm as indicated by LUDIN (1965) and LUDIN et coll 1967) or the diameter at the site of the first bifuracation (OFSTAD et coll 1969) Cases in which for any reason A could not be determined have been discarded from the respective part of the investigation In the presence of multiple renal arteries of diameters A_1 A etc the tabulated value of A was arrived at from the formula $A = (A_1 + A + \ldots)^1$ in spite of the formula $A \leqslant (A_1 + A + \ldots)^1$ being more strictly correct The average value of A was 7 82 + 0 958 mm in the group of normals

Parameter $B = A^2/W$ Although according to the definitions given by LUDIN (1967) estimated autopsy weight W (Fig 4) in this equation refers only to kidneys in which there is neither hydronephrosis nor an expansive lesion in the present work W and B were likewise estimated for hydronephrotic and

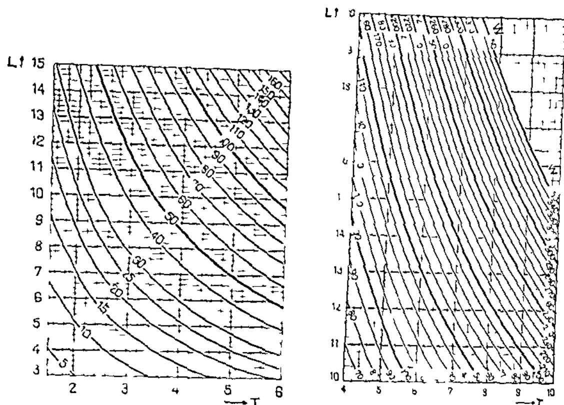


Fig. 4. Nomograms for estimating the weight of single kidneys (curves) from their radiographic length L and width T as measured in urograms or angiograms computed from the formula $W = 0.491 \times (L \times T)$[illegible]. Left: Small kidneys. Right: Normal sized or enlarged kidneys (Ludin 1967).

Methods

Aortography

Urografin 76% was injected through a transfemoral catheter during the Valsalva manoeuvre. The resulting hypotension narrows the aorta, but in the renal arteries a calibre reduction has never been observed, even in young subjects (Ludin 1966).

The renal artery orifices are sometimes situated somewhere on the ventral or dorsal circumference of the aorta rather than on its true lateral aspect. This may be due either to anatomic variation or axial torsion of the abdominal aorta secondary to arteriosclerosis. This was overcome when the renal artery orifice was not clearly demonstrated in the last third of the adult series with another set of films exposed with the patient turned obliquely to an angle estimated from the initial course of the superior mesenteric artery. This second series usually defined the origin of the renal artery and indicated any abnormality of the proximal main vessel (Fig. 2). Two arteries supplying the same kidney

Table 2

Absolute and relative frequencies of multiple renal arteries, an abnormal asymmetry factor F, abnormal kidney weight W, marked or slight funnel shape of renal artery origin and abnormal clearance values in the various clinical groups of the adult series. N normals, H hypertensives, IN chronic interstitial nephritis, PN chronic pyelonephritis, TB renal tuberculosis, GN glomerulonephritis, PK polycystic kidneys, HN hydronephrosis, RC renal cyst, TU tumour, TC kidney contralateral to tumour, TR renal injury, UL urolithiasis, HG hypoplasia, CH compensatory hypertrophy, AN renal artery aneurysm

Number of	N	H	IN	PN	TB	GN	PK	HN	RC	TU	TC	TR	UL	HG	CH	AN
Patient (P)	(106) 70	165	17	28	11	17	16	32	15	30	32	8	9	6	13	4
Kidneys (K)	(157) 105	285	[illegible]	47	16	29	29	37	15	30	32	9	10	6	13	4
Multiple arteries (K)	24	56	6	8	3	3	6	5	1	–	6	1	2	–	[illegible]	[illegible]
	23	*20*	[illegible]	*17*	*19*	*10*	*21*	*13*	*7*	–	*19*	*11*	*0*	–	*15*	*50*
0.45 ≤ F ≤ 0.55 (P)	(34)* 0	50	7	14	5	5	1	11		[illegible]	[illegible]	2	3	6	5	2
	–	*30*	*41*	*50*	*45*	[illegible]	*33*	*34*	[illegible]	[illegible]	[illegible]	[illegible]	*30*	*100*	*84*	*50*
−2 SD > W > +2 SD	(25)* 0	52	11	18	2	7	22	13	[illegible]		7	1	4	6	8	2
	–	*18*	*33*	*38*	*1*	[illegible]	*76*	*35*			[illegible]	*11*	*40*	*100*	*61*	*50*
Funnel shaped renal artery origin (K)	–	4	3	4	2	1	2	8	–	2	–	1	–	1	–	–
	–	*1*	*11*	*14*	[illegible]	*3*	*7*	[illegible]	–	*7*	–	*11*	–	*17*	–	–
Same slight change only (K)	3	5	1	4	1	1	–	1	–	–	–	–	–	–	–	–
	3	[illegible]	*4*	*14*	*6*	*3*	–	*3*	–	–	–	–	–	–	–	–
Clearance values available (P)	3	88	14	13	1	13	6	5	–	–	–	3	2	1	3	4
	4	*53*	[illegible]	*46*	*9*	*76*	*37*	*16*	–	–	–	*37*	*20*	*17*	*23*	*100*
PAH clearance abnormal	–	7	1	–	–	–	1	–	–	–	–	–	–	–	–	–
	–	*8*	*7*	–	–	–	*17*	–	–	–	–	–	–	–	–	–
Inulin clearance abnormal	–	7	1	–	–	1	1	2	–	–	–	1	–	–	2	–
	–	*8*	*7*	–	–	*8*	*17*	*40*	–	–	–	*33*	–	–	–	–
Both clearance values abnormal	–	6	12	7	1	6	2	1	–	–	–	–	–	1	–	[illegible]
	–	*7*	*86*	*54*		*46*	*33*	*0*	–	–	–	–	–		–	*50*

* Before elimination of cases from group of normals

when possible, cystic kidneys, except in the presence of marked renal deformation by mass lesions An easy method for computing B from the radiographic length and width of the kidney and the renal artery calibre is indicated in Fig 5 The average value of B in adult kidneys was 0 358 ± 0 0963 mm /g

The arterial 'tapering parameter' i e the relative difference between the calibre at one (D_1) and three (D_3) cm from the origin $C = (D_1 - D_3)$ $100/D_1$ per cent Only single renal arteries were considered here and otherwise unsuitable cases were excluded as for the calculation of the diameter of single renal arteries

Finally, the following numerical values were calculated

Limits of normal kidney size MOELL (1956) calculated the average renal area and its standard deviation for right and left kidneys from a small material of 25 male and 25 female healthy young individuals The corresponding weight values were determined monographically from these mean values and their double standard deviation (LUDIN 1967) Disregarding sex and the side of the kidney in question, the upper and lower limits of normal estimated weight were assumed to be 111 g and 239 g although HODSON (1967b) mentions that bilateral very large kidneys are occasionally met with in apparently normal people

An asymmetry factor I was calculated from the estimated weight values of the right W_R and the left kidney, W_L $I = W_L$ $100/(W_R + W_L)$ per cent A difference in length of 1 cm between approximately normal sized left and right kidneys would result in a value of I of approximately 45 7 or 54 5 per cent (LUDIN 1967) The kidneys of all patients with a value of $I \leqslant 45$ or $I \geqslant 55$ per cent were considered abnormal

Clearance values The renal plasma flow had sometimes been determined by the PAH clearance method and the glomerular filtration rate by the inulin clearance (Table 2) Split investigations were available in a minority of patients only The results were tabulated in terms of multiples of a single standard deviation from the normal mean values

Clinical classification in the adult series

The material was classified according to the final clinical diagnosis based on biopsy or autopsy findings in only a minority of patients No patient, except for the normals was excluded from any group The parameters of only one kidney could sometimes be included in one group because either radiographic measurements were possible only on the one side or the contralateral kidney had a different lesion In the latter cases some doubt sometimes existed as to

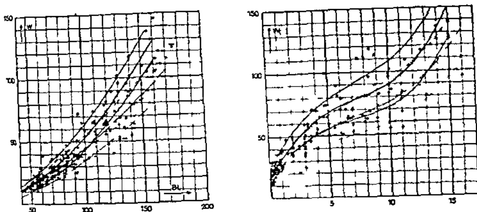


Fig 6 Regression of the weight of normal kidneys on body length or age of children Left Regression of kidney weight W (ordinate) on body length BL (abscissa) ● and — Urographic material (KACI 1970) W estimated from radiographic kidney length (LUDIN 1967) ■ and Autopsy material (HIGGINS 1970) In both series W is ultimately based on values determined at autopsy As a whole the two regression lines differ significantly from each other ($p < 0.001$) in very young individuals however of a body length below 80 cm the difference is not significant ($p > 0.05$) The discrepancy between the regression lines is probably best explained by a difference in sampling in that normal kidneys were included in HIGGINS material wher as most kidneys in LUDIN's (1967) series were diseased The discrepancy may be due to a difference in average relative blood content or elasticity of the organs at autopsy Right Regression of W on age of child *a* The difference between the two regression lines is significant ($p < 0.001$)

the abuse of analgesics and absence of obstruction or urolithiasis As compared with the group of normals the mean age in pyelonephritis was 7 years higher in males and 4 years lower in females The proportion of females was much higher in pyelonephritis or interstitial nephritis (75 0 or 64 7 per cent) than among normals (36 2 per cent $p < 0.001$) This is in agreement with the sex distribution in other reports (BEESON 1967) This group also includes three patients in whom nephrectomy resulted in the relief of significant hypertension

Paediatric series

Whereas in adults normal renal weight is well known from autopsies as well as from calculations from roentgenograms (LUDIN 1967) much less information is available regarding the paediatric age group (ROESSLE & ROULET 1932 KARN 1962 LUDIN 1967) An attempt was therefore made to estimate normal kidney weight as a function of age or body length based on three sources

Autopsy series (HIGGINS 1971) comprising 218 children of age 15 years and under 55 per cent of whom were males The cause of death had been accident or acute respiratory disease in about one third each of the series acute infectious

whether the ipsilateral kidney was put into the correct group, i.e. normals or hypertensives. Since minor involvement of the contralateral kidney could not be excluded on the ground of clinical records in cases of unilateral disease both kidneys in cases of chronic pyelonephritis or interstitial nephritis were invariably considered to be abnormal. Obstructive atrophy, one of the most commonly occurring renal diseases (HODSON 1967b), had received no attention from clinicians or radiologists at the time, such cases most probably were classified as interstitial nephritis, pyelonephritis or hydronephrosis. Some comments will be given about individual groups.

Normal adult kidneys. From this group of 157 kidneys (Table 2), 52 (36 patients) were excluded for the following reasons. In 46 kidneys the asymmetry factor, *F*, or the weight, *W*, was abnormal. In another 6, the patient was over 70 years of age. In 57 (70 patients, Table 2), no renal abnormality nor hypertension was recorded. In 20 (10 patients) the diagnosis was haematuria of unknown (probably extrarenal) origin, and in 28 kidneys the contralateral kidney was affected (8 renal cysts, 6 hydronephrosis, 5 urolithiasis, 4 injury, 3 tuberculosis, 2 abscess).

Systemic hypertension. This group comprised (1) patients in whom hypertension was a clinical diagnosis and no renal abnormality was detected. Since the ophthalmologic findings were not systematically recorded, because the variability of blood pressure readings is notorious and since the duration of the hypertensive state is known exactly in but a minority of patients, no attempt was made to grade this group any further. (2) patients with normal renal findings in whom a significant hypertension was detected but not included in the final diagnosis. (3) the contralateral kidney in hypertensive cases with renal arterial stenosis (cf. OFSTAD et coll. 1969), hydronephrosis, etc.

The presence of nephrosclerosis, based on clearance or biopsy examinations, was mentioned in a number of clinical records. Since no significant difference could be found in the arterial parameters between hypertensives with or without nephrosclerosis nor in the contralateral kidney in cases with renal artery stenosis, these subgroups were tabulated together.

Chronic interstitial nephritis and chronic pyelonephritis. The clinical diagnostic criteria of chronic pyelonephritis were: Lumbar pain, a history of urinary infection, the presence of obstruction or urolithiasis. During the last half year period the clinical cases falling under the heading bacterial interstitial nephritis were distinguished from pyelonephritis, for the purpose of the present investigation all such cases were tabulated under pyelonephritis. The clinical criteria of chronic interstitial nephritis were: No history of urinary infection, a history of

a function of $\bar{B} = 0.405 \pm 0.0867$ and W in KAGIS and HIGGINS series The resulting regressions of A on body length (Fig 11) or age, a (Fig 12) failed to differ significantly from the corresponding regressions of A on BL or a in the normal group of the paediatric aortographic series (Figs 11 12)

Among the 127 children (242 kidneys) 109 (208 kidneys) were classified into 7 groups (Figs 12 13) The remaining group miscellaneous conditions affecting 18 children (34 kidneys) was made up of cystic dysplasia (1) immature kidney rotation (2) gross asymmetry of renal size of unknown origin (4) severe hypertension (1) arterial stenosis (2) nephritis (2) tuberculosis (1), tumour (2) and displacement by masses (3)

Autopsy material

This included several centimetres of abdominal aorta above and below the renal arteries and a few centimetres of renal artery on either side The distal end of the aorta the renal arteries and all other branches arising from the aorta were ligated Ligation of the numerous small aortic branches without distorting the aortic or renal artery wall proved to be somewhat difficult. The proximal inlet of the aorta was then closed by a perforated rubber stopper connected with a fluid lever system allowing fixation of the specimen with formalin under a constant fluid pressure of 150 cm The preparation was extended in a frame in order to harden it in a position and length corresponding as nearly as possible to its anatomic shape fixation being completed the specimens were removed from the frame and filled with Urografin 30 % Roentgenograms were obtained with the vessel filled at the same pressure When as often occurred the renal arteries did not arise from the lateral aspect of the aorta suitable profile views were obtained Histologic sections were subsequently prepared in a longitudinal direction through the aortic and renal artery wall stained with haematoxylin eosin van Gieson and sometimes with PAS

Results

Adult aortographic series

Renal artery calibre A the parameter B and the tapering parameter C were statistically independent of age sex and blood pressure on admission in agreement with the observations of OFSTAD et coll (1969) Table 2 presents the number of kidneys as well as the prevalence of significant asymmetry of renal size in the various groups

Renal artery calibre A The diameter of normal renal arteries in EDSMAN S (1957) material ranged in 95 per cent of cases between 6 1 and 9 7 mm in males or 4 6 and 8 2 mm in females Renal function was normal or only

disease in 15 per cent, drowning in 7 per cent, intoxication in 5 per cent and brain tumour in 3 per cent, together with some rarer conditions. The interval between death and autopsy had been less than 24 hours in 79 per cent, between one and two days in 17 per cent, and longer than 2 days in 4 per cent of the series. No distinction was made between the sexes. Only the compound weight value of both kidneys was usually available, half its value being tabulated (Fig. 6).

Urographic series (KAGI 1970) comprising 115 children (178 kidneys) of the same age group as in the autopsy series, 39 per cent of whom were males. From the radiographic length, L, of the kidney the weight was estimated from the formula $W = 0.10201 \times L^{3}$ (LUDIN 1967) as a function of age and body length (Fig. 6).

Aortographic series (normal kidneys, present investigation), comprising 27 children (50 kidneys). Again, the values of W were estimated according to LUDIN (1967). The calibre of the renal arteries was measured at a distance of about 1 cm from the aortic origin in infants and very young children and about 2 cm in those between 4 and 10 years of age. The cases were reclassified from the history and clinical, histologic and laboratory findings but without recourse to angiographic measurements.

The mean value of B in the group of normals was 0.405 ± 0.0867. No significant difference existed between B of single and duplex kidneys ($p > 0.05$). The difference of B between children and adults ($B = 0.358 \pm 0.0963$) is significant ($p \approx 0.001$). Obviously, in its $\bar{B}$ value the paediatric group ($\bar{B} = 0.405 \pm 0.0867$) is intermediate between the adult angiographic series ($\bar{B} = 0.358 \pm 0.0963$) and WOJTOWICZ' material ($B = 0.422 \pm 0.0981$), the difference between the latter two groups is also significant ($p < 0.001$). Most probably these differences reflect varying criteria in clinical diagnosis rather than a variation of $\bar{B}$ with age. Correspondingly, when correlating the values of B in normal children with age the inclination of the straight regression line failed to differ from zero ($p \geqslant 0.05$). 0.42 ± 0.09 is probably a fair normal value of B. It appears uncertain whether the standard deviation amounting to more than 20 per cent of the mean is due to sampling criteria or true variations in the kidney perfusion/weight ratio. It should be noted that, in experimental investigations relating perfusion to kidney weight (FONTAINE et coll. 1969) as well as in the normal values of the PAH clearance in the human subject (REUBI 1970), the single standard deviation about the mean amounts to 15 to 20 per cent.

Values of the children's body length, BL, in the paediatric group of normals were available in about half of the patients only. A was therefore calculated as

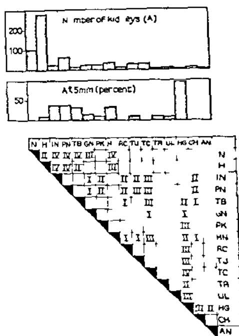


Fig 8 Statistical analysis of values of renal artery calibre A Top Number of kidneys included in the various clinical groups Second diagram from top Relative frequency of values of A $\leq$ 5 ml ( ) Lowermost diagram Statistical significance of difference of values of A between clinical groups (IV probability of error P extremely small $\chi >$ 30 III $p < 0\ 001$ II $p < 0\ 01$ I $p < 0\ 05$ no sign $p<0\ 05$) Abbreviations same as in Table 2

statistically significant difference On the other hand the difference in incidence of narrow arteries between normals and hypertensive cases was significant due to the large number of kidneys in these groups and some heterogeneity of the group of hypertensives The group of glomerulonephritis was intermediate between hypertensives and interstitial nephritis-pyelonephritis the difference between these extremes was highly significant

These data suggest that abnormality of a kidney is highly probable when the renal artery calibre at about 3 cm from its origin is 5 mm or less If hydronephrosis can be ruled out the condition most likely to be present is interstitial nephritis-pyelonephritis although tuberculosis or glomerulonephritis have to be considered as well The arterial calibre may be normal in the presence of slight disease

Parameter B A diminution of this perfusion/weight ratio may result from two basic conditions i e either an increase in renal weight such as occurs in polycystic kidneys or hydronephrosis or a decrease of renal artery calibre The latter is almost certainly due to decreased renal perfusion such as is observed in interstitial nephritis-pyelonephritis or to a lesser degree in tuberculosis or post traumatic states (Figs 7 9)

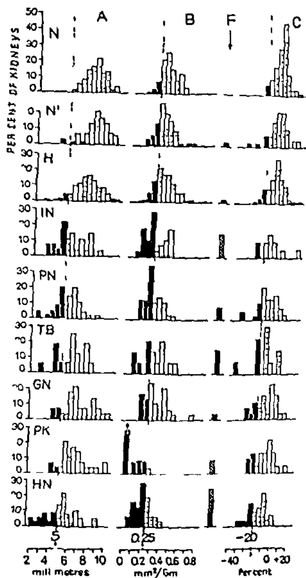


Fig 7 Frequency distribution of renal artery calibre at about 3 cm from origin *A* parameter *B* tapering parameter *C* and funnel shaped renal artery origin *F* in various groups of the adult material (N' group excluded from normals other groups as in Table 2) Ordinate (identical for all diagrams) Relative frequency abscissa *A* (mm) *B* (mm²/g) *C* (%) Vertical dotted lines Approximate boundary between normal and abnormal values (*A* = 5 mm *B* = 0 25 mm²/g *C* = 20 (cf Figs 8 9 10)

slightly reduced in the series of OFSTAD et coll when the renal artery calibre was greater than 6 5 mm The elimination of cases in the present series with abnormal or abnormally asymmetric kidney weight from the group of normals resulted in the absence of renal arteries of a calibre of 5 mm or under (Figs 7, 8)

Whereas narrow arteries were not observed in the groups comprising renal cysts, kidneys contralateral to tumours and compensatory hypertrophy, they occurred in a high proportion in the groups of interstitial nephritis-pyelonephritis, tuberculosis, hydronephrosis and renal 'hypoplasia The number of kidneys in the last group was small so that comparison with normals failed to reveal a

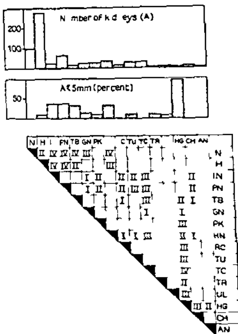


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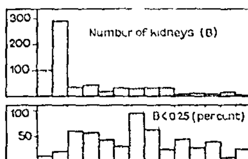


Fig. 9. Values of B: presentation as in Fig. 8. Second diagram from top: Relative frequency of values of $B \leqslant 0.25$ mm⁴/g (%)

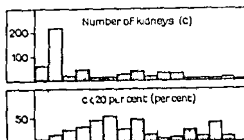


Fig. 10. Values of C: presentation as in Figs 8 and 9. Second diagram from top: Relative frequency of values of $C \leqslant -20$ %

It is again possible that a kidney not enlarged by polycystic disease or hydronephrosis may be pathologic when the parameter $B \leqslant 0.25$, when the most likely cause will be interstitial nephritis-pyelonephritis, although tuberculosis and old injury would have to be considered as well. $B = 0.24$ is two standard deviations below the probable mean normal value, $\overline{B} = 0.42 \pm 0.09$, the latter figure applies equally to children of all ages (LUDIN et coll. 1969). The evidence available, however, fails to prove completely that when $B \leqslant 0.25$ *this is definite* evidence of pathology because, as stated, no way of ensuring that all kidneys included in the group of normals were free from disease was evident.

Arterial tapering parameter C. Statistical comparison demonstrated that a limiting value of $C = -20$ per cent was more efficient in discriminating between normal and pathologic kidneys than would be $C = -15$ per cent. Kidneys, the arteries of which had a funnel shaped origin (Fig. 7) were included in the group of cases with abnormal values of C even when the artery was nearly isodiametric beyond the part next to the aorta. A significant difference was

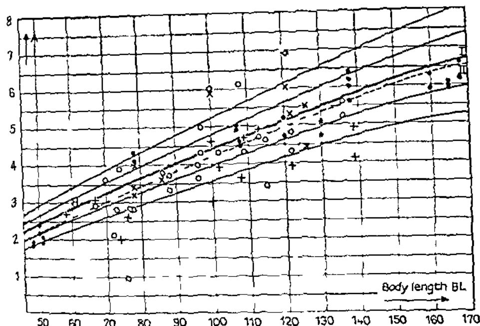


Fig 11 Values of A in children Regression of A of normal kidneys on body length BL calculated from $A = (\overline{B}\,W)$ with the values $\overline{B} = 0.405 \pm 0.0867$ and W as in Fig 6 left This regression line (I) does not differ significantly from the (dotted) one calculated from values observed in aortograms from normal kidneys (II) ($p > 0.05$) ● Normal kidneys × hydronephrosis ◇ kidneys contralateral to hydronephrosis ○ pyelonephritis + hydronephrosis associated with pyelonephritis ≠ partial hydronephrosis in duplex kidney associated with pyelonephritis ■ renal injury □ kidney contralateral to injured kidney

indicated in this regard between normals and hypertensives on the one hand and cases of interstitial nephritis pyelonephritis tuberculosis, glomerulonephritis hydronephrosis and injury on the other It was absent however between glomerulonephritis and interstitial nephritis It *might thus* be suggested that marked tapering of renal arteries ($C >$ —20 *per cent*) indicates the presence of some acquired disorder such as *interstitial nephritis*-pyelonephritis tuberculosis hydronephrosis or possibly, aneurysm or previous injury

Funnel shaped renal artery origin This configuration was observed in extremely narrow renal arteries only A *minority of* such cases may have been missed owing to axis rotation of the aorta or *renal artery* bifurcation close to the aorta (Fig 2) A funnel shaped origin was especially frequent in interstitial nephritis-pyelonephritis *hydronephrosis* and to a lesser degree, in polycystic kidneys (Figs 7 10) The latter two conditions primarily resulting in atrophy are known to be often complicated by pyelonephritis A funnel shaped arterial

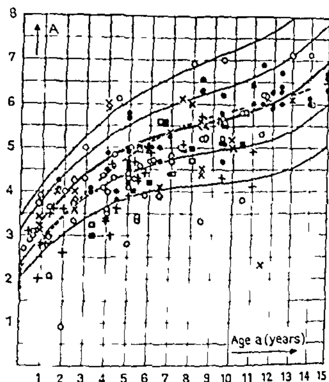


Fig 12 Values of A in paediatric material symbols as in Fig 11 Regression of A on age a calculated as in Fig 11 from values of B as in Fig 6 right Again no significant difference exists between this theoretic regression line and the (dotted) one calculated from empirical values ($p > 0.05$)

origin was also observed in two cases of renal carcinoma in which the artery was nearly occluded some distance along its course and the tumour was largely necrotic or irrigated by dilated lumbar arteries, as well as in a case of nephrocalcinosis

Paediatric aortographic series

Renal artery calibre A Due to the smaller variance about the regression line the regression of arterial calibre on body length (Fig 11, KAGI 1970) would seem to be more useful than the regression of A on age (Fig 12) Low values of A were mainly observed in pyelonephritis, hydronephrosis and kidneys affected by both conditions In these diseases as well as in renal injury most values were within normal limits, probably indicating mild damage Any difference between these findings and those in the adult material may have been due to different sampling The high values may in part have been caused by compensatory hypertrophy which, in other cases may have been depressed by inflammatory changes A was within normal limits or low in hydronephrosis complicated by pyelonephritis

Parameter B Low values mainly occurred in the groups of pyelonephritis hydronephrosis and kidneys affected by both conditions (Fig 13) High values

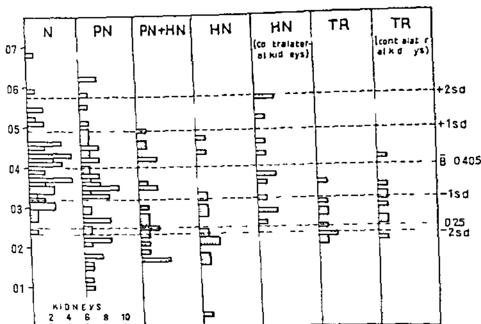


Fig 13 Values of B in children Ordinate Normal value of $\bar{B}$ = 0 405 ± 0 0867 as well as ($\bar{B}$ − 2 SD) ≈ 0 25 i e the lower limit of the normal range in the adult material Clinical groups N normal kidneys HN hydronephrosis PN pyelonephritis PN + HN hydronephrosis associated with pyelonephritis TR renal injury

in these especially in pyelonephritis are probably due to unilateral inflammation with compensatory hypertrophy of the contralateral kidney similar, though slighter changes occur in hydronephrosis B is relatively low in some of the cases of renal injury no explanation can be given for the low values of B in the contralateral kidney

Tapering of renal arteries This appearance was present to a relatively slight degree in 6 children aged 9 months 9 months 4 4 5, 11 and 14 5 years respectively suffering from pyelonephritis hydronephrosis or tuberculosis A slight funnel shape of the renal artery origin was observed in two patients in the younger age group 10 5 and 11 5 years old affected by pyelonephritis the prevalence of this would seem to increase with age (Fig 7), possibly due to progressive reduction of potentially functioning renal parenchyma

Pathology material

The histologic examination demonstrated the following structural alterations of the arterial wall

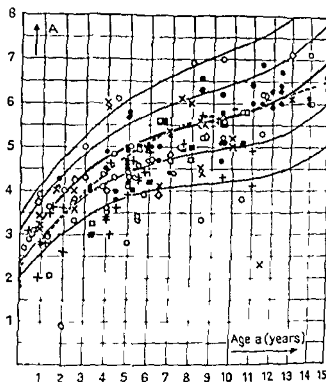


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extend well into the aorta and the renal arteries over a varying distance, they correspond largely to similar changes located in other arteries (Fig 14) Cushions due to intimal fibrosis are usually circumscribed and limited to the arterial orifice predominantly the caudal parts of the inlet circumference they consist of a mesenchymal sponge composed of precollagen and elastic fibres as well as smooth muscle cells (Figs 15 17) These lesions were commonly associated with adaptive fibrosis of small intrarenal arterial branches as described by ZOLLINGER (1966) although there were exceptions Areas of fibrosis in other cushions were situated between arteriosclerotic plaques and the intima (Fig 16)

Fibrotic cushions seem to occur at any age Thus in an elderly woman suffering from hydronephrosis and hydroureter secondary to a gynaecologic malignant lesion pure intimal fibrosis was present at the renal artery orifice the kidney had been found to be non functioning six months before death Autopsy revealed marked hydronephrosis without pyelonephritis (Fig 15)

The role of altered haemodynamics or local geometric factors in the pathogene is of arteriosclerosis is recognised Fibrotic cushions would however also seem to play some part in reducing the calibre of the renal artery The distribution of cu hion like lesions was as follows

Pure intimal fibrosis occurred in 3 cases (4 kidneys) and slight bilateral fibrosis in one of mild bilateral obstruction due to an ill defined malignant lesion in the bony pelvis Marked unilateral fibrosis was observed in another case of severe hydronephrosis of the same aetiology (Fig 15) Fibrosis was pure and advanced on one sid and combined with slight arteriosclerosis on the other side in a case of phenacetin poisoning

Fibrosis was more obvious than arteriosclerosis in 3 cases (4 kidneys) One of them was the phenacetin case just mentioned and another one of pyelonephritis Both renal arteries were affected in a case of amyloidosis due to plasmocytoma

Fibrosis and arteriosclerosis mostly mild were of nearly equal severity in 11 cases (18 kidneys) of pyelonephritis (Fig 16) concomitant partial renal infarction was present in one of these

Relatively severe arteriosclerosis predominated in 3 cases (5 kidneys) 2 of these were cases of pyelonephritis and one of renal arteriosclerosis

Pure arteriosclerosis was present in 7 cases (13 kidneys) The respective kidneys were normal in one polycystic disease was present in 2 pyelonephritis in 2 (Fig 14) and arteriolar nephrosclerosis in 2 cases

A normal orifice was evident in the remaining cases

The prevalence of arteriosclerosis may be due to the age distribution of the material Narrowing and atrophy of the media is probably the primary process and cushion formation either secondary or a manifestation of general arteriosclerosis



Fig 14



Fig 15

Fig 14 Longitudinal section through renal artery orifice Arteriosclerotic cushions with atrophy of the underlying media van Gieson × 5

Fig 15 Fibrotic cusion 5



Fig 16



Fig 17

Fig 16 Mixed cushions predominantly arteriosclerotic with atrophy of the underlying media 3 5

Fig 17 Same case as in Fig 15 × 150 Mesenchymal sponge precollagen and elastic fibres with smooth muscle cells

Atrophic changes of the media, either diffuse as in narrow arteries, or localized as beneath intimal cushions (Figs 14, 16)

Cushion shaped local thickening of the subintimal layer, due either to arteriosclerosis or (sub) intimal fibrosis Lesions of the former variety frequently

extend well into the aorta and the renal arteries over a varying distance they correspond largely to similar changes located in other arteries (Fig 14) Cushions due to intimal fibrosis are usually circumscribed and limited to the arterial orifice predominantly the caudal parts of the inlet circumference they consist of a mesenchymal sponge composed of precollagen and elastic fibres as well as smooth muscle cells (Figs 15, 17) These lesions were commonly associated with adaptive fibrosis of small intrarenal arterial branches as described by ZOLLINGER (1966) although there were exceptions Areas of fibrosis in other cushions were situated between arteriosclerotic plaques and the intima (Fig 16)

Fibrotic cushions seem to occur at any age Thus in an elderly woman suffering from hydronephrosis and hydroureter secondary to a gynaecologic malignant lesion pure intimal fibrosis was present at the renal artery orifice the kidney had been found to be non functioning six months before death Autopsy revealed marked hydronephrosis without pyelonephritis (Fig 15)

The role of altered haemodynamics or local geometric factors in the pathogene is of arteriosclerosis is recognised Fibrotic cushions would however also seem to play some part in reducing the calibre of the renal artery The distribution of cu hion like lesions was as follows

Pure intimal fibrosis occurred in 3 cases (4 kidneys) and slight bilateral fibrosis in one of mild bilateral obstruction due to an ill defined malignant lesion in the bony pelvis Marked unilateral fibrosis was observed in another case of severe hydronephrosis of the same aetiology (Fig 15) Fibrosis was pure and advanced on one sid and combined with slight arteriosclerosis on the other side in a case of phenacetin poisoning

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Discussion

This investigation is based on the assumption that (1) the square of the renal artery calibre is more or less proportional to renal blood flow and kidney weight (2) alterations in the average renal blood flow result in renal artery calibre modification taking place over a period of weeks and months Calibre adaptation is prevented by arteriosclerotic stiffening of the mural tissues The correlation between the square of the renal artery calibre blood flow is thus most probably closer in young than in elderly subjects, this view appears to be supported by experimental work (OLIN 1971)

The time required for calibre adaptation appears to be roughly the same in the respective clinical *conditions as in the animal experiments mentioned* (IDBOHRN 1956, WIDEN 1958) Thus in cases of acute renal functional shut down such as in ureteric obstruction by a calculus, aortography has demonstrated that the renal arteries taper but slightly or not at all, the calibre still being within normal limits The same holds true in normovolaemic shock even when the mesenteric arteries and their branches are markedly constricted, in agreement with KANE (1968) The renal arteries in hypovolaemic shock tend, however, to narrow more rapidly and to a higher degree (KULIC & ABRAMS 1968, LAVENDER & SHERWOOD 1971) Similarly, OLSSON & LUNDERQUIST (1963) reported narrowing and tapering of the renal arteries one month or later following injury whereas a short time after the trauma the same arteries appeared normal, a similar observation was made by ELKIN et coll (1966)

Except in renal hypoplasia a condition discussed below, reduction of renal blood flow and thus narrowing of the renal arteries may be due to loss of potentially functioning parenchyma from atrophy, scarring or replacement by other pathologic tissues

Atrophy may result either from senile changes, including primary arterial disease or pressure exerted by surrounding structures The parameters *A B* and *C* have failed to correlate significantly with the patients age Due to its lack of homogeneity, the material as a whole was not suited to demonstrate senile renal atrophy *Pressure leading to atrophy may be exerted by cysts as in* polycystic disease, or via the pelvis calyceal system as in hydronephrosis or back pressure kidneys These conditions are often associated with pyelonephritis (HODSON & EDWARDS 1960 ZOLLINGER 1966) The arteries undergo secondary rarefaction pari passu with parenchymal atrophy (IDBOHRN 1956), especially when infection supervenes (ZOLLINGER 1966) The arterial calibre was accordingly normal in the series in cases of moderate or severe *hydronephrosis* or polycystic disease, the arteries were narrow and tapering was marked

As compared with atrophy, replacement of renal parenchyma by scar tissue is the result of a group of pathologic changes far more problematic from

nosologic, aetiologic and diagnostic points of view (ZOLLINGER 1966, BEESON 1967, HEPTINSTALL 1967, and others) Thus, commenting on *chronic pyelonephritis*, BEESON wrote many lesions may in fact represent chronic *renal inflammation* and scarring due to some other process (vascular disease, chemical injury, metabolic disease, etc) with a terminal acute bacterial infection and continued a recent tendency to use the term chronic pyelonephritis more or less as a matter of convenience, for chronic renal disease of unknown cause even when evidence of past or present bacterial *infection* is lacking This *practice seems* almost *certain* to impede advance in understanding, since the existence of various other disorders may thus be obscured

Renal biopsy often reveals the presence of some chronic infiltration or scarring of indeterminate origin (MUEHRCKE & PIRANI 1967) This would seem to correspond to the relative prevalence of *subnormal values of parameters* A B and C *in the groups of normals* hypertensives etc in the present adult series it might also be a reason for the relatively low mean value of B in the adult group of normals

On the other hand pyelonephritis of focal distribution is said to escape detection by needle biopsy in a proportion of cases (MUEHRCKE & PIRANI) The *term focal distribution seems* to contribute to the semantic difficulties existing ROLLESTON et coll (1970) in their paediatric radiologic investigation of the relationship of infantile vesico-ureteric reflux to renal damage thus mention that a focal distribution of the lesions was evident at urography only *in a small* minority of cases with gross reflux the present authors feel this to be contrary to the *findings* of HODSON et coll (1962) HODSON (1967b) In the absence of histologic evidence it might be assumed that in the majority of their cases obstructive atrophy rather than pyelonephritic scarring might have been present in most cases (HODSON 1970) The term interstitial nephritis (ZOLLINGER) *in other cases of chronic inflammatory* renal diseases might have its merits The lesions in question present however on a histologic level *a more* or less focal distribution (ZOLLINGER) From an angiographic point of view it may be of some interest to point out in this context that lowering of the blood pressure in hypertensives under Valsalva conditions has led to a subtotal arrest of *perfusion in cases of subchronic glomerulonephritis* a true non focal process, exclusively this phenomenon has however never been *observed in other* conditions including arteriolar nephrosclerosis pyelonephritis and interstitial nephritis (LUDIN 1965b)

Macroscopically arteriolar nephrosclerosis is unevenly distributed It is most likely that in the group of adult *hypertensives* presented significant nephrosclerosis occurred much more frequently than abnormal *values of* A or B Moreover in two cases of proved recent *malignant* nephrosclerosis the arterial

parameters were within normal limits These observations may suggest that recent nephrosclerosis does not necessarily lead to any abnormality of the arterial parameters and that in the small proportion of hypertensives with subnormal values of *B*, scarring rather than recent nephrosclerosis had been responsible for the renal artery abnormalities, especially when the changes are asymmetric

Renal blood flow is a prerequisite of glomerular filtration as well as fluid and solute output, but, except in renal ischaemia, does not appear to be considered a functional parameter of great clinical importance In spite of its variance about the mean value, amounting to about 20 per cent, the fairly constant ratio of renal blood flow to kidney weight suggests that owing to the close correlation between renal blood flow and the square of the renal artery diameter, the latter factor reflects within limits the volume of potentially functioning renal parenchyma It is an established principle of renal, hepatic and pulmonary physiology (EPSTEIN 1966) that organ failure manifests itself only when a considerable proportion of functioning parenchyma is lost, due to the remarkable functional reserve Although aortography is not considered to be the method of choice in assessing renal function, this procedure may well yield useful information regarding renal functional capacity Thus PORSTMANN (1970) points to the usefulness of angiography in the detection and follow up of chronic pyelonephritis in childhood

The question arises whether the origin of a so called unilateral dwarf kidney is hypoplasia or inflammation, especially in a child occasionally even in an adult In some degree against earlier opinions held predominantly on the European continent, hypoplasia is a rare condition, it was recorded about once in 10 000 cases in the autopsy material of ZOLLINGER (1966) Dysplasia was eight times and the pyelonephritic dwarf kidney over forty times as common as what was thought to be true hypoplasia ZOLLINGER points out that pyelonephritis as well as dysplasia is frequently superimposed on hypoplasia and that the pathologic differentiation between renal dysplasia and pyelonephritis is often extraordinarily difficult His opinion from a physiologic point of view is that when uncomplicated neither of these two congenital conditions leads to hypertension nor to other clinical signs relatively few such patients would therefore be subjected to aortography

The widely accepted view of HODSON et coll (1962) is that both symptomatic and subclinical renal inflammation in infancy or childhood promoted by severe vesico ureteric reflux and often di regarded as some (minor) attacks of pyelitis, inhibits the growth of the affected organ It obviates any *major increase* in renal blood flow and thus diminishes the circumferential growth of the *irrigating* artery and, when the damage is unilateral, leads to compensatory hypertrophy of the contralateral kidney This pathogenetic theory, substantiated by a

wealth of experience (HODSON & WILSON 1965 ROLLESTON et coll 1970 and others), appears much more acceptable than the opinion of BACHMANN & SCHAEFER (1967) who postulated that compensatory hypertrophy of the con tralateral kidney is a criterion of renal hypoplasia or dysplasia, 10 out of 11 of those patients, however, were hypertensive

Significant tapering of renal arteries in a distal direction is encountered only in narrow vessels When the arterial calibre is extremely reduced tapering is limited to the arterial segment close to its aortic origin, which then assumes the shape of a funnel Both tapering and funnel shaped main arteries are thus observed exclusively in those kidneys in which for some reason a reduction or perfusion from a previous higher level with a secondary reduction of renal artery size has occurred A good proportion of unilateral dwarf kidneys are however supplied by narrow arteries in which there is neither tapering nor a funnel shaped inlet The present authors earlier held the view (LUDIN et coll 1969) shared by TEMPLETON & THOMPSON (1968) that this arterial configuration would prove the congenital nature of the condition Tapering was however rare in the paediatric material a somewhat funnel shaped inlet being observed in but two aged 11 5 and 10 5 years suffering from hydronephrosis and pyelonephritis respectively This is in full agreement with the experience of PORSTMANN (1970)

Further evidence of the acquired nature of the great majority of unilateral dwarf kidneys in which there is no tapering nor a funnel like arterial origin may be derived from a consideration of the six present adult patients clinically classified as hypoplasia (Table 2) Only two of these aged 21 and 42 years, were normotensive The others aged 16 40 52 and 56 years were frankly hypertensive and of these two underwent nephrectomy with subsequent return to normal blood pressure The artery belonging to the small kidney of the older normotensive patient had a markedly funnel shaped origin The younger of these two patients underwent nephrectomy the kidney removed was the only one with histologic appearances probably consistent with hypoplasia

Conclusions

Certain parameters were investigated by abdominal *aortography* in 458 adults and 127 children which included normal patients and those suffering from renal disease These consisted of (1) the width of the main renal arteries A (2) their degree of tapering C (3) the proportion of those with abrupt funnelling of the arteries at their aortic origin and (4) a parameter $B = 1/W$ W being the kidney weight estimated nomographically from radiographic measurements

These data and a previous correlation investigation together with the quantitative application of a physiologic theory suggested that (1) renal blood flow is a near quadratic function of renal artery calibre, (2) the square of the arterial diameter reflects approximately the mass of potentially functioning renal parenchyma, (3) adaptation of renal artery width to altered renal blood flow takes place at a rapidly decreasing speed within a period of weeks or months, (4) tapering of the main renal artery indicates acquired renal mass shrinkage, (5) such shrinkage when excessive is associated with funnelling of the proximal artery and a narrow distal lumen, and (6) the histologic basis of this process appears to consist of atrophy of the main renal artery media and the formation of subintimal fibrotic or arteriosclerotic cushions

Normal values are presented of renal weight and artery width both in adults and children, in the latter related to age or body length A main renal artery calibre of 5 mm or under or a tapering of 20 per cent or more suggests disease, renal pathology may be expected in children or adults when the value of *B* is 0 25 mm /g kidney or less The data also suggest that the appearances of arterial changes vary to some extent in relation to the aetiology of the renal condition

SUMMARY

Renal artery occlusion and stenosis is a common cause of potentially curable arterial hypertension The present investigation was however mainly directed to a decrease in the calibre or tapering of extrarenal parts of the renal arteries The material consisted of 458 adults and 127 children

ZUSAMMENFASSUNG

Verschluss und Stenose der Nierenarterie sind eine gewohnliche Ursache der potentiell heilbaren arteriellen Hypertension Die vorliegende Untersuchung war jedoch hauptsächlich auf eine Herabsetzung des Kalibers oder eine Zuspitzung des extrarenalen Teils der Nierenarterien ausgerichtet Das Material umfasste 458 Erwachsene und 127 Kinder

RÉSUMÉ

L'occlusion et la stenose de l'artere renale sont une cause commune d'hypertension arterielle qui peut etre curable Cependant le present travail concerne surtout une diminution du calibre ou un effilement des parties extrarenales des arteres renales Les auteurs ont examine 458 adultes et 127 enfants

REFERENCES

BACHMANN D und SCHAEFER P Nierenmissbildungen Angiographische Befunde Fortschr Rontgenstr 107 (1967) 50

BEESON P B Urinary tract infection and pyelonephritis *In* Renal disease Second edition, p 396 Edited by D A K Black Blackwell Oxford and Edinburgh 1967

EDSMAN G Angionephrography and suprarenal angiography Roentgenologic study of normal kidneys expansive renal and suprarenal lesions and aneurysms Acta radiol (1957) Suppl No 155

ELKIN M MENG C H and DE PAREDES R G Roentgenologic evaluation of renal trauma with emphasis on renal angiography Amer J Roentgenol 98 (1966) 1

EPSTEIN F Disorders of the urinary tract In Principles of internal medicine Fifth edition p 834 Edited by T R Harrison et coll McGraw Hill New York 1966

FONTAINE J L IMBS J L FOUCHER G et coll La mesure du débit sanguin rénal en expérimentation Ses applications a la perfusion du rein Angiology 20 (1969) 647

FRIEDENBERG M J EISEN S and KISSANE J Renal angiography in pyelonephritis glomerulonephritis and arteriolar nephrosclerosis Amer J Roentgenol 95 (1965) 349

FRY D L Acute vascular endothelial changes associated with increased blood velocity gradients Circulat Res 22 (1968) 165

HEPTINSTALL R H The limitations of the pathological diagnosis of chronic pyelonephritis In Renal disease Second edition p 350 Edited by D A K Black Blackwell Oxford and Edinburgh 1967

HIGGINS T A J Das Gewicht normaler Nieren im Kindesalter Thesis University of Basle Switzerland 1971

HODSON D J (a) The radiological contribution toward the diagnosis of chronic pyelonephritis Radiology 88 (1967) 857

— (b) Radiology of the kidney In Renal disease Edited by D A K Black Second edition Blackwell Oxford and Edinburgh 1967

— Personal communication (1970)

— and EDWARDS D Chronic pyelonephritis and vesico-ureteric reflux Clin Radiol 11 (1960) 219

— and WILSON S Natural history of chronic pyelonephritic scarring Brit med J 2 (1965) 191

— DREWE J A KARN M N and KING A Renal size in normal children A radiographic study during life Arch Dis Childh 37 (1962) 622

IDBOHRN H Renal angiography in cases of delayed excretion in intravenous urography Acta radiol 42 (1954) 333

— Renal angiography in experimental hydronephrosis H Ohlsson Lund 1956

— and MUREN A Renal blood flow in experimental hydronephrosis Acta physiol scand 33 (1957) 200

KAGI U Beurteilung der Nierengrosse im Sauglings- und Kindesalter Thesis University of Basle Switzerland 1970

KANE J F The effect of hypotension on renal function Brit J Surg 55 (1968) 178

KARN M N Radiographic measurements of kidney section area Ann hum Genet 25 (1962) 379

KITTREDGE R D HEMLEY S D KANICK V and FINBY N The atrophic renal artery Amer J Roentgenol 92 (1964) 309

KRAMER K and DEETJEN P Sodium reabsorption and oxygen consumption in the mammalian kidney In Symposium on oxygen in the animal organism p 411 Pergamon Press New York 1964

KUPIC E A and ABRAMS H L Renal vascular alterations induced by haemorrhagic hypotension Invest Radiol 3 (1968) 345

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REFERENCES

BACHMANN D und SCHAEFER P Nierenmissbildungen Angiographische Befunde Fortschr Rontgenstr 107 (1967) 50

BEESON P B Urinary tract infection and pyelonephritis *In* Renal disease Second edition p 396 Edited by D A K Black Blackwell Oxford and Edinburgh 1967

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MYCOPLASMA PNEUMONIAS

by

R STENSTROM ELLI JANSSON and R VON ESSEN

Mycoplasma pneumoniae is well established as an important causative agent of pneumonia (CLYDE & DENNY 1963 GEORGE et coll 1967 FOY et coll 1970) Opinions on the roentgenologic manifestations of this infection differ considerably HERBERT (1966) stated The pulmonary infiltrate is bronchopneumonic in type Most authors (JANSSON et coll 1964 ALEXANDER et coll 1966 THOMBS 1967 ROSMUS et coll 1968 and FOY et coll) have however considered the roentgenologic signs to be mainly pneumonitic or interstitial in character As regards situation mycoplasma pneumonia usually involves the lower lobes on the two sides (JANSSON et coll 1964 and THOMBS) FOY et coll and GRAYSTON et coll (1965) reported however that the condition was unilateral in 86 to 90 per cent of cases As to pleural effusion HERBERT wrote The pleural effusion is so rare as to suggest different diagnosis HERS (1968) stated Pleural effusion was seen in young children but was rare in adults, FINE et coll (1970) reported pleural effusion in 6 out of 29 cases of mycoplasma pneumonia and concluded The possibility of a mycoplasma pneumonitis should not be dismissed merely because of the presence of a pleural effusion

These contradictory findings appeared to justify a roentgenologic investigation of a series of cases of the condition

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LAVENDER J P and SHERWOOD T The renal cortex angiogram and renal blood flow studies of renal cortical perfusion under differing functional states Brit J Radiol 44 (1971) 505

LUDIN H Tomographische Bestimmung der Nierengrosse Fortschr Rontgenstr 95 (1961), 215

— Considerations regarding the pathogenesis of arteriolosclerosis in the pulmonary and systemic vascular bed Med thorac 21 (1964) 384

— (a) Zur quantitativen Bestimmung des relativen Nierenarterienkalibers Fortschr Rontgenstr 103 (1965) 604

— (b) Arteriographische Feststellung einer Erhohung des renalen Blutstromungswiderstandes bei der diffusen Glomerulonephritis Fortschr Rontgenstr 103 (1965) 690

— Aortography Fluid dynamics and technical problems Acta radiol (1966) Suppl No 256

— Radiologic estimation of kidney weight Acta radiol Diagnosis 6 (1967) 561

— FERE M FEHR H and THOLEN H Correlation of renal size renal artery calibre and effective renal plasma flow in man Acta radiol Diagnosis 6 (1967) 296

— JUBIN E J och KAUFMANN H J Njurartarernas avgång från aorta (In Swedish) Communication 30th congress of the Northern Soc Med Radiol Helsinki 1969

MOELL H Size of normal kidneys Acta radiol 46 (1956) 640

MUEHRCKE R C and PIRANI C L Percutaneous renal biopsy In Renal disease Second edition p 197 Edited by D A K Black Blackwell Oxford and Edinburgh 1967

OISTAD J GJERSVIK E and KOLSAKER L Diameter of the renal artery and kidney function in patients with parenchymatous renal disease renal artery stenosis and renal carcinoma Acta med scand 186 (1969) 533

OLIN T Personal communication (1971)

OLSSON O and LUNDERQUIST A Angiography in renal trauma Acta radiol Diagnosis 1 (1963) 1

PORSTMANN W Renal angiography in children Methods indications and results In Progress in paediatric radiology Vol III p 51 Edited by H Kaufmann S Karger Basel & New York 1970

REUBI F Nierenkrankheiten Zweite Auflage Hans Huber Bern 1970

RODBARD S IKEDA K and MONTES M An analysis of mechanics of post stenotic dilatation Angiology 18 (1967) 349

ROESSLE R und ROULET F Mass und Zahl in der Pathologie Springer Berlin 1932

ROLLESTON G L SHANNON F T and UTLEY W L F Relationship of infantile vesicoureteric reflux to renal damage Brit med J 1 (1970) 460

TEMPLETON A W and THOMPSON I M Aortographic differentiation of congenital and acquired small kidneys Arch Surg 97 (1968) 114

THOMA R Untersuchungen uber die Histogenese und Histomechanik des Gefässystems Ferdinand Enke Verlag Stuttgart 1893

THURAU K Renal hemodynamics Amer J Med 36 (1964) 698

WIDEN T Renal angiography during and after unilateral ureteric occlusion Berlingska Boktryckeriet Lund 1958

WOJTOWICZ J Relationship of the surface parameters of the kidney to the size of the renal artery Invest Radiol 2 (1967) 231

ZOLLINGER H U Niere und ableitende Harnwege In Spezielle pathologische Anatomie Herausgegeben von W Doerr und E Uehlinger Springer Berlin Heidelberg & New York 1966

Table 2

Duration of roentgenologic changes in 96 cases of mycoplasma pneumonia

Duration	No of cases
Two weeks	8
One month	27
Two months	9
Three months	2
Total	96

The lobe distribution of the 96 cases was as follows right upper and middle lobes (8) left upper lobe (7) right lower lobe (11), left lower lobe (14), various lobes of the right lung (8) various lobes of the left lung (6) both lower lobes (12) and other combinations of both lungs (30) Bilateral pneumonias thus appeared in 44 per cent of cases (children 55 per cent)

The application of the classification of SCHMID gave the following distribution 15 cases of exudative alveolar pneumonia (10 lobar segment pneumonias and 5 bronchopneumonias) and 81 cases of interstitial-oedematous pneumonia

Atelectasis was present in 63 per cent (children 72 per cent) bullous emphysema in 45 per cent (children 57 per cent) and enlarged hilar glands in 49 per cent of cases (children 64 per cent) Pleural effusion was evident in 11 per cent and signs of pleural reaction in 63 per cent of cases Pleural effusion was more frequent in the exudative alveolar than in the interstitial-oedematous cases Six of the 10 lobar pneumonia cases had evidence of leucocytosis An abscess developed later in a case of lobar pneumonia

Twenty cases had slight 54 moderate and 22 marked characters, migratory pneumonia was observed in 6 cases The pneumonia was considered secondary in 17 cases and was usually associated with a cardiovascular or a chronic pulmonary process e g tuberculosis bronchiectasis emphysema or both

No correlation between the level in the titre of cold agglutinins with the type of pneumonia was evident Autoimmune aberrations (JANSSON et coll 1971) were apparent in 14 cases and the number of lobar pneumonias was twice as high in these as in the interstitial oedematous cases

The duration of the roentgenologic changes appear in Table 2

The following cases were selected to illustrate typical roentgenologic appearances in mycoplasma pneumonias All the cases had cold agglutinins in a titre of ≥ 32

Table 1

Age distribution and occurrence of cold agglutinins according to age in 96 cases of mycoplasma pneumonia

Age in years	1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–60	61–70	> 70	Total
No. of cases	6	15	21	12	11	7	10	5	6	3	96
Cold agglutinin positivity	5	14	16	11	10	4	7	2	2	1	72

Material and Methods. A serologic or bacteriologic diagnosis of mycoplasma pneumoniae infection was made in 106 cases admitted during the period April 1963 to March 1970. The methods used for complement fixation serology and isolation have been published and in addition cold agglutinins and certain other autoimmune aberrations have been assayed (JANSSON et coll. 1971). An unequivocal roentgenologic diagnosis of pneumonia was made in 96 of these cases which form the material of this retrospective analysis.

A roentgen examination in frontal and lateral projection was made on admission with additional tomography if necessary and later repeated at variable intervals. The pertinent clinical and laboratory data have been published elsewhere (JANSSON et coll. 1971).

Of the 96 patients 50 were male and 46 female. The age distribution appears in Table 1. 42 of the patients were from one to 15 years old, the youngest was one year, and the oldest 83 years old. Cold agglutinins in a titre ≥ 32 were evident in 77 per cent of the cases, and the distribution of the cold agglutinins in the different age groups appears in Table 1.

The roentgenologic classification of the pulmonary changes was based on the description of the pathology of pneumonia as given by SCHMID (1968), who distinguished between exudative alveolar and interstitial oedematous conditions as judged from the dominating features.

Characteristic signs for the first group were either homogeneous infiltration, as in lobar segment pneumonia, or an ill defined spotty structure, as in bronchopneumonia. Typical appearances in the latter were a fine reticular banded structure, as a sign of the interstitial tissue reaction.

Results

The pneumonic foci were distributed in the lungs as follows: right side 27 cases, left side 27 cases and bilaterally 42 cases.



Fig 2 Case 2 Partly homogeneous infiltration of nonsegmental distribution in both lungs Bronchi in the left lower lobe containing air

Case 4 Boy aged 8 with a history of coughing vomiting and fever for 14 days was admitted with a temperature of 38 4 C a leucocyte count of 7 100 and an ESR of 101 mm Roentgen examination indicated left lower lobe pneumonia and signs of left sided pleural effusion (Fig 4) 30 ml sterile serous fluid were aspirated Marked regression with slight residual infiltration was evident about six weeks later with only pleural adhesions after a further six weeks

Discussion

Mycoplasma pneumonia is a disease mostly of young subjects (JANSSON et coll 1964 1971 GRAYSTON et coll GEORGE et coll, HERS FOY et coll) It occurred in 68 per cent of the present material in the age group 1 to 30 years with 44 per cent of the patients from 1 to 15 years

The correlation between mycoplasma pneumoniae infection and cold agglutinin production has also been reported to be more constant in young people (BIBERFELD 1971) as compared to the older age groups an observation confirmed in the present investigation However no correlation between the roentgenologic type of pneumonia and the development of cold agglutinins was apparent



Fig 1 Case 1 Reticular and acinar infiltration with small bullous emphysema scattered throughout both lungs Signs of atelectasis and pleural reaction

Case reports

Case 1 Woman aged 31 with a week s history of fever and cough was admitted with a temperature of 38 6 C a leucocyte count of 6 500 and an ESR of 83 mm Roentgen examination revealed reticular and acinar infiltration throughout both lungs (Fig 1) There were signs of atelectasis bullous emphysema and pleural reaction Regression occurred within a fortnight with normal appearances six weeks later

Case 2 Boy aged 9 with a week s history of cough vomiting and fever was admitted with a temperature of 38 8° C a leucocyte count of 10 400 and an ESR of 45 mm Roentgen examination the same day disclosed homogeneous areas of infiltrations of nonsegmental distribution in the right upper and left lower lobes with the bronchi in the left lower lobe still containing air (Fig 2) Atelectasis bullous emphysema enlarged hilar glands and pleural reaction were also observed Later control films demonstrated a basal reticular structure The roentgenologic changes persisted for a month

Case 3 Man aged 21 with a week s history of cough pain in the neck and fever was admitted with a temperature of 39 3 C a leucocyte count of 8 400 and an ESR of 66 mm the Waaler Rose titre was 64 and cryoprecipitins 2 per cent The mycoplasma pneumoniae culture was positive Roentgen examination of the lungs revealed abnormal reticular and acinar appearances with atelectasis pleural reaction and septal infiltration on the left side (Fig 3) Similar infiltration was present in the right lung nine days later but had almost completely regressed after a week

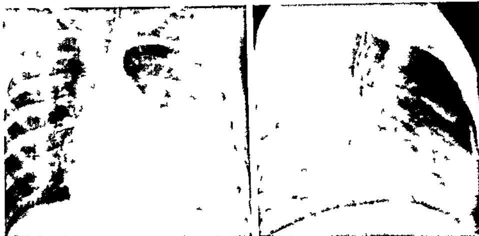


Fig 4 Case 4 Pneumonia of left lower lobe and pleural effusion

Foy et coll reported that 86 per cent of mycoplasma pneumonias were unilateral On the other hand several other authors have stated that the pneumonia may often be bilateral (JANSSON et coll 1964 THOMBS HERS) Forty four per cent of the present cases had bilateral pneumonia (children 55 per cent) the lower lobes being the most frequent sites in conformity with many other reports (JANSSON et coll 1964 HERS THOMBS) GEORGE et coll were of the opinion that single lobe pneumonia was typical of mycoplasma pneumonia (in 90 per cent) this was the rule in 42 per cent of the present cases

GEORGE et coll and HERBERT stated that pleural effusion was rare in this condition although according to many authors it appears to occur frequently (MUFSON et coll 1963 DECANCQ & LEE 1965 GEORGE et coll THOMBS FINE et coll FOY et coll) Pleural effusion was evident in 11 per cent and pleural reaction in 67 per cent of the present cases As might be expected an effusion was more frequent in the exudative alveolar than in the interstitial oedematous cases

The rate of occurrence of atelectasis and bullous emphysema confirmed previous findings (GEORGE et coll JANSSON et coll 1964 and HERS) Enlarged hilar glands were more frequently evident in children than in adults as observed by ROSMUS et coll

The roentgenologic duration of mycoplasma pneumonia exceeded a month in 11 per cent of the cases which tallies with the figures given in the literature (JANSSON et coll 1964 GRAYSTON et coll HERS) The disease pursued a prolonged course particularly in the cases with pleural effusion and secondary pneumonic infiltration



Fig. 3. Case 3. Reticular and acinar infiltrations in left lower lobe with atelectasis, pleural reaction and septal infiltration.

The roentgenologic changes caused by mycoplasma pneumoniae have usually been considered to be interstitial in nature (JANSSON et coll. 1964, ALEXANDER et coll., THOMBS, ROSMUS et coll., FOY et coll.). The interstitial oedematous type also dominated the present cases being present in 84 per cent. The roentgenologic appearances were similar to those described by STENSTRÖM et coll. (1962) in ornithosis pneumonia. The present authors agree with ROSMUS et coll. that an increase in oedematous reaction in the course of pneumonia superimposes an acinar pattern onto the basic reticular, banded infiltration. Reticular areas may, however, also be observed at the periphery of the infiltration in the lobarsegmental and bronchopneumonic cases of the exudative alveolar type. On regression of the process the reticular pattern, presumably present although obscured within the homogeneous infiltration, reappears.

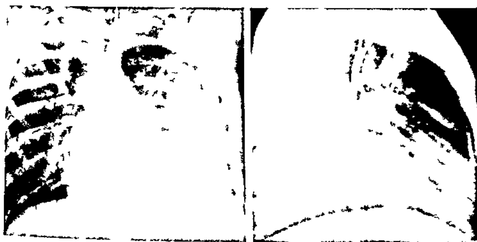


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Conclusions

The roentgenologic appearances in mycoplasma pneumonia varied in adults as well as in children. However, the dominating features indicated that about 80 per cent of the cases were of the SCHMID's interstitial-oedematous type and characterized by irregular reticular and reticular acinar infiltrations. Many of the remaining cases exhibited reticular changes at some stage. The pneumonias were often associated with pleural effusion, enlarged hilar glands, atelectasis and small bullous emphysema. Bilateral changes occurred in about 50 per cent of the cases, more often in children than in adults.

The roentgenologic appearances are similar to those in many types of virus pneumonia and ornithosis. A suggestion of any possible epidemiologic factor or a positive cold agglutinin test may however often assist in the diagnosis. As the specific aetiologic diagnosis depends either on the use of paired sera or on the isolation of a slow growing and fastidious organism, early roentgenologic diagnosis may be valuable for the therapeutic management of the patient.

SUMMARY

Ninety six cases of confirmed mycoplasma pneumonia were considered in retrospect. No pathognomonic features to distinguish this condition from virus pneumonia were apparent although certain characters were common. The importance of the cold agglutinin test is emphasized.

ZUSAMMENFASSUNG

Sechsundneunzig Fälle von nachgewiesenen Mycoplasma Pneumonien wurden retrospektiv nachuntersucht. Es waren keine pathognomonischen Eigenheiten vorhanden, die diesen Zustand von einer Viruspneumonie abgrenzt, obwohl gewisse Zeichen gemeinsam waren. Die Bedeutung des Kälteagglutinin Tests wird hervorgehoben.

RÉSUMÉ

Quatre vingt seize cas confirmés de pneumonie à mycoplasma pneumoniae ont été étudiés rétrospectivement. Il n'y a pas de caractère pathognomonique permettant de distinguer cette affection de la pneumonie à virus, elles ont certains caractères communs. Les auteurs insistent sur l'importance du test de l'agglutinine froide.

REFERENCES

ALEXANDER, E. R., FOY, H. M., KENNY, G. E., KRONMAL, R. A., MCMAHAN, R., CLARKE, E. R., MACCOLL, W. A. and GRAYSTON, J. T.: Pneumonia due to Mycoplasma pneumoniae. New Engl. J. Med. 275 (1966), 131.

BIBERFELD, B.: Antibody responses in Mycoplasma pneumoniae infection in relation to serum immunoglobulins especially IgM. Acta path. microbiol. scand. Section B 79 (1971), 620.

CLYDE W A and DENNY F W The etiology and therapy of atypical pneumonia Med Clin N Amer 47 (1963) 1201
DECANCQ G H and LEE F A Mycoplasma pneumoniae pneumonia Massive pulmonary involvement and pleural effusion J Amer med Ass 194 (1965) 1010
FINE N L SMITH L R and SHEEDY P F Frequency of pleural effusions in mycoplasma and viral pneumonias New Engl J Med 283 (1970) 790
FOY H M KENNY G E McMAHAN R MANSY A M and GRAYSTON J T Mycoplasma pneumoniae pneumonia in an urban area J Amer med Ass 214 (1970) 1666
GEORGE R B WEILL H RASCH J R MOGABGAB W J and ZISKIND M M Roentgenographic appearance of viral and mycoplasmal pneumonias Amer Rev resp Dis 96 (1967) 1144
GRAYSTON J T ALEXANDER E R KENNY G E CLARKE E R FREMONT J C and MACCOLL W A Mycoplasma pneumoniae infections Clinical and epidemiologic studies J Amer med Ass 191 (1965) 369
HERBERT D H The roentgen features of Eaton agent pneumonia Amer J Roentgenol 98 (1966) 00
HERS J F P Clinical aspects of infection with Mycoplasma pneumoniae Proc roy Soc Med 61 (1968) 1325
JANSSON E WAGER O STENSTROM R KLEMOLA E and FORSSELL P Studies on Eaton PPLO pneumonia Brit med J 1 (1964) 142
— VON ESSEN R and TUURI S Mycoplasma pneumoniae pneumonia in Helsinki 1962—1970 Epidemic pattern and autoimmune manifestations Scand J infect Dis 3 (1971) 51
MUFSON M A SANDERS V WOOD S C and CHANOCK R M Primary atypical pneumonia due to Mycoplasma pneumoniae (Eaton agent) Report of a case with a residual pleural abnormality New Engl J Med 268 (1963) 1109
ROSMUS H H PARE J A P MASSON A M and FRASER R G Roentgenographic patterns of acute mycoplasma and viral pneumonitis J Canad Ass Radiol 19 (1968) 74
SCHMID F Erkrankungen der Lunge im Säuglings- und Kleinkindesalter *In* Encyclopedia of medical radiology IX/3 p 806 Edited by L Diethelm O Olsson F Strnad H Vieten and A Zuppinger Springer Verlag Berlin Heidelberg New York 1968
STENSTROM R JANSSON E and WAGER O Ornithosis pneumonia with special reference to roentgenological lung findings Acta med scand 71 (1962) 349
THOMBS D D Cold agglutinin positive pneumonia A review of thirty cases in children Ohio St med J 63 (1967) 1171

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PULMONARY SEQUESTRATION IN A RABBIT

by

D. HANSEN and T. OLIN

Pulmonary sequestration has been described in man, the horse, and the cow (DAVIDSON 1956). The discovery of this condition in a laboratory rabbit presented an opportunity for its investigation.

Case report

A 2 kg Swedish Lund rabbit was examined by coeliac axis angiography, the intention being to perform pharmacoangiography in this area. A fine catheter (OPP 60 Portex, England OD/ID = 1.22/0.67 mm) was introduced into the femoral artery and the coeliac axis catheterized during fluoroscopy (ADAMS et coll. 1965). The tip of the catheter was located in what was considered to be the hepatic artery. Injection of contrast medium (Isopaque Cerebral Nyco, Norway) outlined a large artery (2.1 mm diameter) with a tortuous cranial course that passed through the diaphragm and filled a small basal segment of the left lower lung (Fig. 1) and its draining vein. A large shunt appeared as the ascending aorta was outlined 1.5 to 2.0 seconds from the start of the injection. The blood flow through the aberrant artery was so large that an injection flow rate, which under normal circumstances would have been sufficient to fill the coeliac axis completely, was now barely enough to *fill the abnormal* branch. The abnormal lung segment measured almost 3.0 cm × 1.2 cm in a lateral projection. A chest survey revealed a moderately enlarged heart but otherwise no abnormality. *Th8* and Th9 were anomalous and were of the butterfly type, the corresponding *ribs* were also abnormal, some being large, broad and clumsy while others were underdeveloped and thin with no true vertebral articulation.

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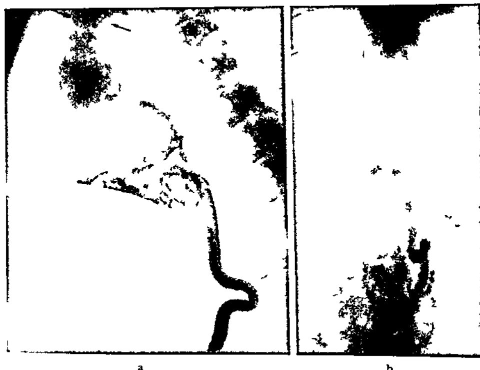


Fig 1 Selective angiography of the aberrant artery feeding the sequestrated pulmonary segment a) Lateral Large shunt through the lobe emptying into the left atrium The ascending aorta is also filled with contrast medium (→) b) A p Bony anomalies of the low thoracic vertebrae and ribs

Pharmacoangiography of the aberrant artery was then performed 0 3 μg norepinephrine being injected into the abnormal artery 15 to 20 seconds before repeat angiography The artery itself failed to change in caliber but the flow through the pulmonary segment was impaired and filling of the left atrium was delayed for 4 5 seconds A considerable amount of contrast medium passed back into the other branches of the coeliac axis indicating diminished flow through the pulmonary segment the degree of filling of the abnormal segment was also somewhat diminished Repeat angiography after 1 0 μg of norepinephrine produced approximately the same appearances as after 0 3 μg Additional angiography was performed after a small dose (0 3 IU) of synthetic lysine vasopressin (Postacton Ferring Sweden) The flow in the abnormal artery was slightly impaired although the caliber of the main stem was unchanged A marked effect of diminished flow was observed in some of the branches of the coeliac axis e g the hepatic and splenic arteries An attempt to occlude the shunt was then made A fine guide wire of stainless steel was introduced through the catheter for a few mm beyond its tip An electric current was applied between the tip of the guide wire and the



Fig 2 Angiography of the coeliac axis Lateral The aberrant artery is thrombosed electrically through the catheter

subcutaneous tissue in the groin The positive pole was in the artery and 6 to 8 mA was used to create a clot into which a small amount of barium sulfate suspension (Micropaque Damancy England) was then injected to prevent fibrinolysis Repeat angiography indicated that the aberrant artery was closed (Fig 2) The catheter was withdrawn and the incision in the groin sutured Three days later further catheterization was performed Remnants of barium sulfate were evident in the abnormal pulmonary segment but the aberrant artery was again patent and there was marked shunting Autopsy demonstrated the presence of a small accessory lobe associated with the left lower lobe of the lung Microscopy of the accessory lobe disclosed minor bronchiectases and slight emphysema The arteries had very thick walls mainly due to hyperplasia of the media vascular changes that were considered to be secondary to hypertension The veins were wider than normal

Five rabbits from the same litter were also examined but failed to reveal any abnormalities

Discussion

An increasing number of cases of pulmonary sequestration have been diagnosed by angiography Aortography and selective injection into the aberrant artery have proved to be important not only in the diagnosis but also for the demonstration of the precise anatomy of the abnormal vessel The blood supply of the sequestra

tion in human subjects may arise anywhere from the thoracic aorta in the hilar region to the coeliac axis in the abdomen (SMITH 1956), as occurred in this rabbit Shunting from the aorta to the left atrium through the sequestration has been mentioned as a possible complication to the malformation (KERGIN 1952, RANNIGER & VALVASSORI 1964), but has apparently not previously been demonstrated so clearly Pharmacoangiography disclosed that the aberrant artery per se did not react to norepinephrine, whereas the small vessels in the sequestration contracted Microscopic examination of the feeding artery has revealed that the wall is of elastic tissue similar to that of the aorta and contains no appreciable amount of smooth muscle cells (PRYCE 1946 SMITH 1956) Pharmacoangiography, as compared to ordinary angiography probably has no major diagnostic value in cases of pulmonary sequestration

Shunting of blood is the only indication for surgery unless pulmonary sequestration occurs in conjunction with considerable anomalies of the lung Dye dilution examinations of the output from the heart with or without balloon occlusion of the feeding artery should make it possible to estimate the flow through the shunt It was possible temporarily to thrombose the aberrant vessel with a weak electric current in the present experiment but the thrombus disappeared after a short time the barium sulfate suspension that was added as a stabilizing agent was insufficient to prevent this process Another agent e g horse tail hair or iron filings might have better served the purpose Antifibrinolytic treatment with tranexamic acid might also have been of value

Several theories as to the etiology of intralobar and extralobar (lower accessory pulmonary) sequestration have been proposed based largely upon the evaluation of clinical cases The two conditions have been linked (PRYCE 1946) and separated (SMITH 1956) and the blood vessels used to explain the abnormality The present case exhibited a varying arterial blood supply of coeliac origin with venous drainage of the usual intralobar sequestration description The anatomic configuration however was that of a lower accessory lung (extralobar) with its own pleura The presence of skeletal abnormalities however, implicates a wider embryologic disorganization The classifying of pulmonary sequestration as extralobar and intralobar seems unwarranted in a case like this

SUMMARY

Pulmonary sequestration in a rabbit was examined by selective angiography The feeding vessel arose from the coeliac axis with the drainage to the left atrium through a large shunt The accessory lobe had its own pleura and certain abnormalities of the ribs and thoracic spine were evident

ZUSAMMENFASSUNG

Beim Kaninchen wurde ein Fall von Lungen-Sequestration mittels selektiver Angiographie untersucht. Das zubringende Gefäss entsprang von der A. coeliaca, das abführende Gefäss endete im linken Vorhof. Der überzählige Lappen hatte eigene Pleura, Rippenanomalien und Missbildungen der dorsalen Wirbelsäule waren Begleiterscheinungen.

RÉSUMÉ

Les auteurs ont examiné par angiographie sélective sur un lapin la séquestration pulmonaire. Le vaisseau nourricier provenait de l'axe coeliaque et se drainait dans l'oreillette gauche par un large shunt. Le lobe accessoire avait sa plèvre propre et certaines anomalies des côtes et du rachis dorsal étaient évidentes.

REFERENCES

ADAMS D. F., OLIN T. B. and REDMAN H. C.: Catheterization of arteries in the rabbit. Radiology 84 (1965), 531.

DAVIDSON S. W.: Some anomalies of the respiratory system. J. Fac. Radiol. (London) 8 (1956), 1.

KERGIN F. G.: Congenital cystic disease of lung associated with anomalous arteries. J. thorac. Surg. 23 (1952), 55.

PRYCE D. M.: Lower accessory pulmonary artery with intralobar sequestration of lung; report of seven cases. J. Path. Bact. 58 (1946), 457.

RANNIGER K. and VALVASSORI G. E.: Angiographic diagnosis of intralobar pulmonary sequestration. Amer. J. Roentgenol. 92 (1964), 540.

SMITH R. A.: A theory of the origin of intralobar sequestration of lung. Thorax 11 (1956), 10.

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ABNORMAL PELVIS IN NEWBORN INFANTS WITH DOWN S SYNDROME

by

W MORTENSSON and B HALL

The diagnosis of Down s syndrome (mongolism) in newborns is sometimes made difficult because the signs such as the vaguely abnormal facies are not always easy to evaluate Certain skeletal changes e g dysplasia of the middle phalanx of the fifth finger and the abnormal bony pelvis are however more readily assessed (WARNER 1935 HEFKE 1940 CAFFEY & ROSS 1956 HALL 1964) These abnormalities have been included among the ten signs of significant diagnostic value in newborns with Down s syndrome (HALL 1964)

Dysplasia of the pelvis in Down s syndrome was first described by CAFFEY & ROSS (1956 1958) as flattening of the roof of the acetabulum and widening of the iliac alae and bodies. These changes were assessed quantitatively by measuring the acetabular and iliac angles and halving the totals, this quotient was called the iliac index and was smaller in infants with Down s syndrome (mean 60 range 48 to 87) than in controls (mean 81 range 68 to 97) The index was said to be diagnostic in 4 out of 5 mongoloids. A definite diagnosis could be made from the roentgenograms without calculation of the index in

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Fig. 1. a) Pelvis of a normal newborn. Spina iliaca posterior superior (→), corpus ossis ilii (→). b) Pelvis of a mongoloid newborn. The upper border of the ilium is long and less curved, spina iliaca anterior superior prominent and broad. Spina iliaca posterior superior cannot be seen, the corpus is short and not clearly outlined against the iliac ala.

3 out of 4 subjects. Most relevant publications have stressed the diagnostic value of the iliac index in Down's syndrome (for review, see KAUFMANN 1964). HALL (1964), however, indicated that analysis of the morphology of the pelvis is a more reliable diagnostic procedure than the iliac index method.

This paper concerns a clinical and experimental investigation on the sources of error in the determination of the iliac index and a comparison of the dependability of the individual diagnosis based on the index from roentgenograms.

Material. This consisted of 26 mongoloids and 17 normal infants examined within the first ten days of life, 8 of the mongoloids were re-examined one and 4 years later. A follow-up of the newborn controls was replaced by examinations of 16 normal children aged 1 year and 12 aged 4 years. All patients with Down's syndrome had typical clinical features. Cytologic examination revealed a regular trisomy G karyotype in 25 patients and a G/D translocation trisomy in one patient.

Specimens of the bony pelvis of 7 dead mongoloid and 5 non-mongoloid infants were examined roentgenographically.

Methods. The patients were examined supine with the legs adducted and extended until muscle resistance was encountered. This usually produced a tilt of the pelvis that caused projection of the tip of the coccyx or sacrum close to an imaginary line connecting the centers of the Y cartilages. The tip was however always projected below this line when the older child was lying

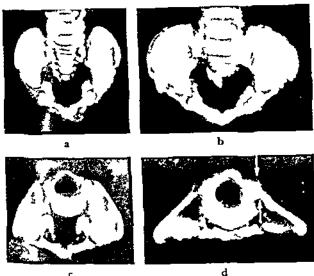


Fig 2 *Pelvic preparations* from a normal (a c) and a mongoloid (b d) new born a) b) in the same projection as at roentgen examination c) d) axial projections In the mongoloid pelvis the iliac bones lie almost in the frontal plane — outwardly rotated in the sacro-iliac joints but the dorsal part of the alae is in the sagittal plane (⟶)

comfortably Care was taken to avoid rotation of the child about its longitudinal axis the central beam was directed perpendicularly to the symphysis

Examination of the dissected specimens was made with the pelvis attached to a stand which permitted graded rotation of the pelvis around its transverse axis — backward and forward tilting (HALL 1964)

The acetabular and iliac angles were measured and the morphology of the pelvis was analysed roentgenographically The following findings were considered to be compatible with the pelvic abnormality of Down s syndrome (1) A long and less curved cranial convexity of the iliac ala Clearly visible spina iliaca anterior superior and a broad pelvis (CAFFEY & ROSS 1956) (Fig 1) (2) Indistinct boundaries of the upper margin of the roof of the acetabular fossa the lateral aspects of the corpus and lower lateral part of the ala of the iliac bone (Fig 1) (3) Spina iliaca posterior superior not demonstrable (KAUFMANN 1964 ANDREN & HALL 1968) (Fig 1)

Results

The appearances of the individual bones of the dissected pelves of mongoloid infants failed to differ from those of the controls except in the part of the iliac alae situated dorsal to the *sacro-iliac joints* This part in the controls lay in the plane between the frontal and the sagittal planes, while in the mongoloids it ran almost parallel to the latter (Fig 2 c d) This explains why the spina

Table 1

Results of direct evaluation of the pelvic morphology in 26 neonates with Down's syndrome. Column 1: Long and less curved cranial convexity of the iliac ala. Column 2: Indistinct boundaries of the upper margin of the roof of the acetabular fossa, the lateral aspects of the corpus and lower lateral part of the ala of the iliac bone. Column 3: Spina iliaca posterior superior not demonstrable. + means that the aberration was obvious, (+) present but less obvious, 0 absence of the aberration, and ? that the condition could not be assessed

Case No	1	2	3	Iliac index
1	0	0	+	80
2	(+)	(+)	+	76
3	+	0	+	72
4	+	(+)	+	71
5	+	+	+	70
6	+	+	+	69
7	(+)	(+)	+	68
8	+	+	?	68
9	+	0	+	68
10	+	+	+	67
11	+	+	(+)	67
12	+	0	+	64
13	+	+	+	63
14	+	+	+	63
15	+	(+)	(+)	61
16	+	(+)	+	59
17	+	(+)	+	59
18	+	+	+	58
19	+	+	+	58
20	+	+	+	57
21	+	+	+	57
22	+	+	+	56
23	+	+	+	54
24	+	+	+	53
25	+	+	+	46
26	+	+	+	45

iliaca posterior superior will be demonstrable in conventional a.p. views of normal infants but not of mongoloids. The position of the iliac bones of the mongoloids also differed from that of the normals. These bones had a closer orientation to the frontal plane, reflecting outward rotation of the sacro-iliac joints (Fig. 2); this gives the characteristic appearances of the pelvis in mongoloids, the roentgenographic features being due to this altered orientation of the os ilium. This means that the iliac ala is projected more en face, while

Table 2

Iliac index in mongoloid and normal infants 0—10 days old

Iliac index	No. of infants	
	Normal	Mongoloid
—50	0	2
51—60	0	9
61—70	3	11
71—80	2	4
81—	12	0
Total	17	26

the corpus is projected more axially so that its lateral border merges with that of the iliac ala and the lateral margin of the roof of the acetabulum.

The abnormal appearances of the dissected pelvis of the mongoloid infants were accentuated at the roentgen examinations on forward tilting and gradually disappeared on backward tilting. Forward tilting of the normal pelves produced appearances evident in mongolism but the spina iliaca posterior superior could be identified and the margin of the roof of the acetabular fossa was relatively distinct. Forward tilting caused a greater reduction in the acetabular and ilium angles in the mongoloid pelves than in the controls. On moderate rotation of the pelvis (about 20°) about the transverse axis, the mean change in the iliac index was 16 in the mongoloid pelves and 9 in the controls.

Technical reasons sometimes made it impossible to define the morphology of the spina iliaca posterior superior or corpus os ilii in the newborns, but the general appearances of the pelves permitted their classification.

Down's syndrome is always associated with characteristic anomalies of varying degree of the pelvis (Table 1). None of the controls exhibited such abnormalities in infancy or later.

No appreciable alteration in the configuration of the pelves became apparent in the two groups during the control period, however, the iliac index decreased especially during the first year, particularly in the patients with Down's syndrome. The iliac indices in the newborns are given in Table 2.

Discussion

The values for the iliac index in normal subjects and those with Down's syndrome agreed with those reported by CAFFEY & ROSS (1956), SCHULTZ-JENA (1959) and KAUFMANN (1964). Though the age ranges in their series

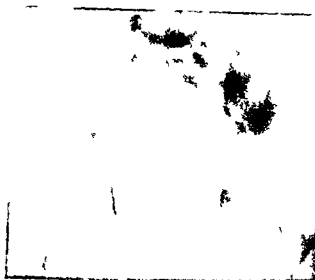


Fig 3 Mongoloid newborn Iliac index 80 The pelvis of normal morphology except that spinae iliacae posterior superior are not demonstrable

were wider, the overlap between the indices in the controls and in those with Down's syndrome was wider in the present series An index below 60 was evident only in mongoloids and above 80 only in normals but for 15 of 20 mongoloids and 5 of 17 controls it lay between 61 and 80 The findings are thus consistent with those of ASTLEY (1963) and GUSTAFSSON (1964)

Roentgenologic examination of specimens of the bony pelvis following different degrees of backward and forward tilting produced variation in the acetabular and iliac angles, an observation also made by BALL & KOMMENDA (1968) and LAYBI & KANE (1968) Reproducible measurements of the acetabular and iliac angles thus require knowledge of the orientation of two axes of the pelvis The longitudinal axis may be easily adjusted and determined although it is difficult to define the rotation of the pelvis about the transverse axis KAUFMANN recommended extension of the patient's legs until resistance was offered by the thigh muscles to assure comparable tilting of the pelvis The objection must however be raised that the degree of rotation varies with the muscle tone, which differs considerably between mongoloid infants and controls, the mongoloid has marked muscle hypotonia It was decided that the pelvis should be tilted to such an extent that the tip of the coccyx or sacrum was projected up to an imaginary line drawn between the midpoints of the Y cartilages Owing to the differences in the number of ossified segments in the coccyx (HESS 1917) and the varying angulation of the sacrum, the pelvis must be rotated to a varying extent to fulfil the criteria, and even this method is accordingly not precise

The pelvis of the newborn consists partly of cartilage which is poorly calcified, the outlines of the skeleton are therefore somewhat ill defined and the points



Fig 4 Mongoloid newborn Iliac index 64 Well defined lateral borders of the corpus ilium and distinct margins of the roof of the acetabulum Prominent spinae iliacae anterior superior broad cranial margins of the alae and absence of demonstrable spinae iliacae posterior superior produce characteristic appearances

necessary for drawing the angles may be difficult to determine A further source of error (ROHLEDER 1950 PALMEN 1961) thus arises particularly in mongoloid newborns in whom the skeletal outlines are less distinct than in normals It is thus evident that (1) the technical imperfection of the method, (2) the fact that it was impossible to standardise the examination conditions and exactly to define the angles to be measured and (3) a considerable overlap between the indices of the normals and the infants with cytologically proved Down s syndrome together suggest that the iliac index method is of little value in the diagnosis of a given case

The purely descriptive evaluation of the pelvic anatomy stimulated the investigators to appreciate the morphologic deviation of the whole pelvis The pelvis was projected in the way described forward and backward tilting failed to reveal the spina iliaca posterior superior This was the sign most easy to assess The appearances of the pelvis however changed so that its morphology might have been interpreted wrongly Variations sometimes made it difficult to estimate the cranial convexity of the iliac alae and the prominence of the spina iliaca anterior superior

The morphology of the pelvis in infants with Down s syndrome varied more widely than in normal infants (Figs 1 b 3 4) although all of the former had abnormal pelves even those with high indices The most reliable sign was that concerning the spina iliaca posterior superior the process being evident in all the normal but in none of the mongoloid infants In one case of Down s syndrome with an iliac index of 80 this was the only abnormality present the

pelvis was otherwise normal The other cases of Down's syndrome, however, had more than one aberration in pelvic morphology

The present results confirm those of ANDREN & HALL (1968) concerning the non demonstrable spina iliaca posterior superior Roentgen examination of normal and mongoloid infants performed by these authors to project the iliac bones axially indicated in most of the mongoloid infants the outward dorsal curvature of the posterior part of ilium was increased' This is the morphologic substratum that explains why the spina is not demonstrable in the common a p projection of the pelvis The authors stated that increased outward curvature of the ilium appeared to be one of the most common signs of mongolism

CAFFEY & ROSS (1958) described the pelvis of one mongoloid infant as normal, but the accompanying illustration indicated backward tilting, which may explain the normal appearances

None of the pelves of the control infants or children demonstrated any single morphologic sign of Down's syndrome The series is small, but may be considered acceptable since mongoloid pelvic dysplasia has never been reported in non mongoloid infants The outward rotation of the sacroiliac joints in cases of bladder exstrophy gives the iliac bones mongoloid appearance, dorsally however the iliac alae are not curved as in Down's syndrome with the result that the spina iliaca posterior is demonstrable The follow up of 8 children with Down's syndrome revealed no appreciable alteration in the configuration of the pelvis, a finding in agreement with that of KAUFMANN (1964) Though dysplasia of the middle phalanx of the fifth finger may sometimes regress (HALL 1970) no tendency to a return to normal of the pelvis was evident in the present material

Pelvic dysplasia of the type occurring in Down's syndrome is probably not pathognomonic although a most useful sign in the diagnosis of mongolism within the first few days of life

SUMMARY

An analysis of the pelvic morphology in aberration of the bony pelvis in Down's syndrome proved better than the CAFFEY & ROSS iliac index method The material consisted of 26 mongoloids and 17 normal infants examined within the first ten days of life and with suitable follow up

ZUSAMMENFASSUNG

Eine Analyse der Beckenmorphologie hinsichtlich Abweichungen des knöchernen Beckens beim Downs Syndrom erwies sich als geeigneter als die Darmbein Index Methode von CAFFEY & ROSS Das Material umfasst 26 mongoloide und 17 normale Kinder die innerhalb der ersten 10 Lebenstage untersucht und später nachuntersucht worden waren

RÉSUMÉ

L'analyse de la morphologie pelvienne concernant les anomalies du bassin osseux dans le syndrome de Down s'est montrée supérieure à la méthode de l'index iliaque de CAFFEY & ROSS. Les auteurs ont examiné 26 nourrissons mongoloïdes et 17 nourrissons normaux au cours des dix premiers jours de la vie et avec une surveillance ultérieure suffisante.

REFERENCES

ANDREN L. and HALL B. Increased curvature of the ilium. A new roentgenological sign of mongoloid pelvis. Child Develop. 10 (1968) 781

ASTLEY R. Chromosomal abnormalities in childhood with particular reference to Turner's syndrome and mongolism. Brit. J. Radiol. 36 (1963) 2

BALL F. and KOMMENDA K. Sources of error in the roentgen evaluation of the hip in infancy. Ann. Radiol. 5/6 (1968) 298

CAFFEY J. and ROSS S. Mongolism (mongoloid deficiency) during early infancy — some newly recognized diagnostic changes in pelvic bones. Pediatrics 17 (1956) 642

— — Pelvic bones in infantile mongoloidism. Roentgenographic features. Amer. J. Roentgenol. 80 (1958) 458

GUSTAFSSON K. H. Down's syndrome. Almqvist & Wiksell, Uppsala 1964

HALL B. Mongolism in newborns. A clinical and cytogenetic study. Acta paediat. (Uppsala) (1964) Suppl. No. 154

— Somatic deviations in newborn and older mongoloids. A follow up investigation. Acta paediat. (Uppsala) 59 (1970) 199

HEFKE H. W. Roentgenological study of anomalies of the hands in one hundred cases of mongolism. Amer. J. Dis. Child 60 (1940) 1319

HESS J. H. The diagnosis of the age of the fetus by the use of roentgenograms. Amer. J. Dis. Child 14 (1917) 397

KAUFMANN H. J. Röntgenbefunde am kindlichen Becken bei angeborenen Skelettaffektionen und chromosomalen Aberrationen. Georg Thieme Verlag, Stuttgart 1964

PALMÉN K. Preluxation of the hip joint. Acta paediat. (Uppsala) (1961) Suppl. No. 129

ROHLEDER. Zur Röntgendiagnostik der Hüftluxation. Z. Orthop. 79 (1950) 95

SCHULTZ-JENA B. S. Röntgenologische Merkmale des Beckens bei Mongolismus. Kinderärztl. Prax. 27 (1959) 141

TAYBI H. and KANE I. Small acetabular and iliac angles and associated diseases. Radiol. Clin. N. Amer. 6 (1968) 215

WARNER E. N. A survey of mongolism with a review of one hundred cases. Canad. med. Ass. J. 33 (1935) 495

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NOMOGRAM FOR MEASURING THE ANTEVERSION ANGLE AND ANGULATION OF FRACTURE FROM ROENTGENOGRAMS

by

PAUL EDHOLM

Most of the numerous methods for computing the anteversion angle rely on the use of complicated nomograms and tables (BILLING 1954, DUNLAP et coll. 1953, JOHNSON 1941, MAGILLIGAN 1956, LEGER 1952, RYDER & CRANE 1953, SCHERTLEIN 1929). Nomograms and trigonometric formulae have also been devised for computing the angulation of a fracture (BOGDANOV 1950) while graphical methods have been evolved for the construction of this and the anteversion angle (LEFEBVRE et coll. 1961, NORMAN 1963).

Practically all the methods necessitate the two projections being perpendicular to each other as well as to the axis of one of the fragments, and the method now presented is based on a nomogram having the same requirements. More general means of measuring angles exist (EDHOLM 1966) but the simplicity and mode of application of the nomogram would appear to warrant its description.

The nomogram consists of an equilateral triangle, each side of which carries a scale of degrees from 0 to 90 (Fig. 1). Each point of the nomogram represents a direction and its surface all possible directions of fragment angulation. The

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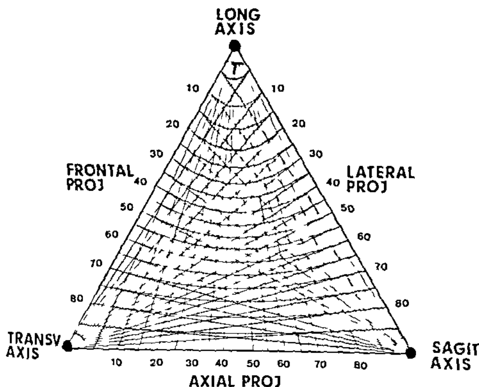


Fig 1 The nomogram

uppermo t vertex indicates the long axis of the extremity the lower left vertex the transverse axis through the fracture and the lower right vertex the sagittal axis The left side of the triangle represents the frontal projection and the right side the lateral projection while the lowermost side is an axial projection of the fracture There are four systems three of them are composed of straight lines from the vertices to the respective scales on the opposite sides while the fourth is made up of curves A straight line in the nomogram indicates a plane so that the systems of straight lines indicate bundles of planes through the three axes. The system of curves indicates a bundle of cones with their vertices in the fracture and with a common axis coincident with the long axis

Angulation of a fracture

Films are exposed in two projections perpendicular to the axis of one of the fragments The directions of projection should coincide with the sagittal and transverse axes of this fragment

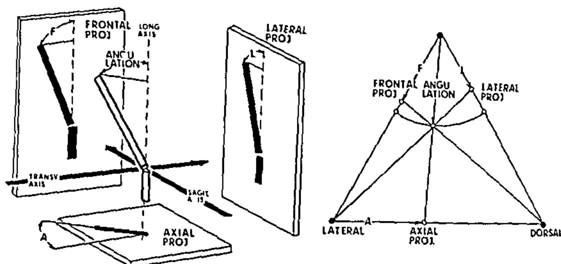


Fig 2 Measurement with the nomogram Left Frontal lateral and axial projections of a fracture with the upper fragment angulated laterally and dorsally Right The angles in frontal and lateral projections F and L respectively are used to construct the angulation and the axial angle A of the fragment

Measuring technique If the angulated fragment be directed cranially, dorsally and laterally these directions are marked on the long, the sagittal and the transverse axes, respectively (Figs 2, 3) The angle between the axis produced of the known fragment and the axis of the other is measured in frontal and lateral films The points on the left and the right sides of the nomogram corresponding to these angles are determined The straight lines from these points intersect at another point through which a curve gives the angulation of the fracture The straight line from the uppermost vertex of the triangle through this point of intersection represents the plane containing the axes of the two fragments the scale reading is the angle that this plane makes with the frontal plane Four angles are involved, namely the two known angles that the fragment makes with the long axis in the two films, and the two unknown angles, the angulation and the angle between the fracture plane and frontal plane The unknown angles may be read off from the nomogram

The anteversion angle

The anteversion angle is usually defined as an angle between two planes that intersect in the ideal axis of the femur, one of these containing the condylar axis of the knee, and the other the axis of the femoral neck The 'ideal axis is drawn from the centre of the condylar axis in the knee through the centre of the cranial portion of the shaft, in other words, the anteversion angle is the angle between the neck and the condylar axis, projected

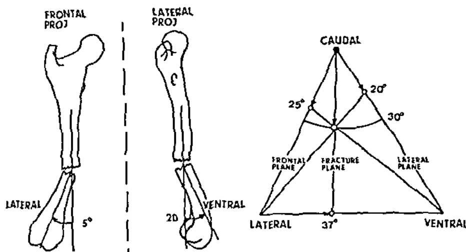


Fig 3 Measurement with the nomogram Left Frontal and lateral projections of a fracture of the femur The lower fragment is angulated laterally and ventrally at angles of 25 and 20 respectively Right These angles are used to compute the angulation (30) and the angle between the frontal and fracture planes (37)

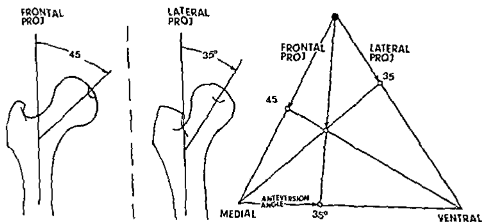


Fig 4 The anteversion angle Left frontal and lateral projections of the upper part of femur Right Use of the nomogram to find the anteversion angle

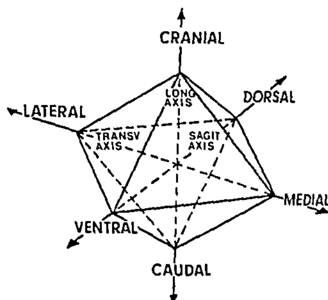


Fig. 5. The eight possible positions of the nomogram form an octahedron.

in the direction of the ideal axis. For practical purposes the anteversion angle may be described as the angle between the neck of the femur and the horizontal plane in an axial projection with the patient supine and the leg hanging vertically. The patient is placed in this position with the femur parallel to the side of the table. Frontal and lateral films of the hip joint are exposed with vertical and horizontal directions, respectively, of the principal ray. Both projections must be perpendicular to the ideal axis of the femur.

Measuring technique. Measurement is made in the two films of the angle between the axis of the femoral neck and the ideal axis produced in the cranial direction (Fig. 4). The angles in the frontal and lateral films lie on the left and right sides, respectively, of the nomogram. The straight lines from these points intersect the line from the uppermost vertex through this intersection meeting the lowermost scale at a point whose scale reading is the anteversion angle. The angle between the ideal axis and the femoral neck, if required, may be read off on the curve through the point of intersection in the nomogram.

Geometry

The nomogram is the result of the following geometric model. A right angled coordinate system is inserted with its origin at the vertex of the angle required with the long axis, the sagittal axis and the transverse axis of the fixed fragment as axes. Let the three axes be intersected by a plane at points equidistant from the origin. These points define an equilateral triangle that constitutes the surface of the nomogram. The eight possible positions of this triangle, cor-

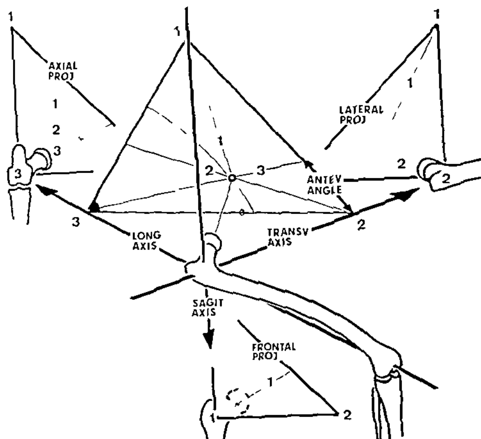


Fig 6 The geometric model of the nomogram in measurement of the anteversion angle Centre Oblique view of the femur the three axes and the nomogram lying on its left side Vertex 3 corresponds to the uppermost vertex of nomogram Lower right and left Frontal lateral and axial projections respectively of the femoral neck and the nomogram The third projection with line 3 is constructed with lines 1 and 2 from frontal and lateral projections to give the anteversion angle

responding to the quadrants form an octahedron (Fig 5) The nomogram is used in the quadrant containing the fragment with an angulation or the femoral neck (Fig 6) this quadrant is easily identified from the two films, and the directions of the three axes that contain this quadrant are marked on the three vertices of the nomogram As the nomogram intersects the three axes it is possible to envisage all three projections in the nomogram at the same time The directions of the fragment itself and its three projections in the nomogram will intersect (Fig 7)

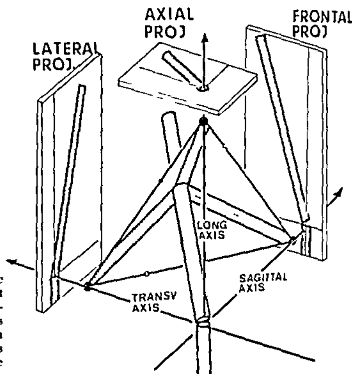


Fig 7 The geometric model The nomogram represents a plane that intersects the three axes of projection in the same quadrant as the fragment The fragment in each projection is envisaged as being projected both on the nomogram and on a film

Construction of the nomogram

The distances corresponding to tan 5, 10, 15 45° were marked off on a straight line, the scale being chosen so that tan 45° corresponded to 10 cm This procedure was repeated in the opposite direction from zero on the scale to produce a line 20 cm long with two tangent scales Three such lines were combined to form an equilateral triangle A system of lines was drawn to the scale, graduated as in Fig 1 on the opposite side from each vertex The nomogram was then ready for measurement of the anteversion angle

The system of curves was constructed as follows Straight lines were drawn on a sheet of paper from a point at 5° intervals to give a system from 0 to 90°, as on a protractor A reference point was marked on the zero line at a distance equal to the side of the nomogram divided by $\sqrt{2}$ — that is $10\sqrt{2}$ The nomogram was placed on this sheet of paper with the uppermost vertex coincident with the reference point on the paper A pin was passed through this common point and the nomogram rotated about it until the end of the line coincided with the 90° line of the underlying system for each line in the nomogram arising in the uppermost vertex All the intersections of this system and the line in question were marked on the line, the curves drawn through these points constituted the required system

SUMMARY

The angulation of a fragment and its direction may be computed from two orthogonal projections of a fracture from the simple nomogram described. The anteversion angle may also be obtained.

ZUSAMMENFASSUNG

Die Winkelbildung eines Fragments und dessen Richtung lassen sich von zwei orthogonalen Projektionen einer Fraktur aus einem einfachen hier beschriebenen Nomogramm berechnen. Der Anteversions-Winkel kann ebenfalls erhalten werden.

RÉSUMÉ

Le nomogramme simple décrit par l'auteur permet de calculer l'angulation d'un fragment et sa direction à partir de deux radiographies orthogonales d'une fracture. On peut obtenir l'angle d'antéversion.

REFERENCES

BACKMAN S. The proximal end of the femur. Acta radiol. (1957) Suppl. No. 146.

BILLING L. Roentgen examination of the proximal femur end in children and adolescents. Acta radiol. (1954) Suppl. No. 110.

BOGDANOV G. A method of determining the true angle of deviation in a fracture. Brit. J. Radiol. 23 (1950) 497.

VAN BRUNT E. A method of measuring the femoral neck in surgical treatment of fractures of the hip. Amer. J. Roentgenol. 76 (1956) 1163.

BRUCHNER H. Theorie und Praxis. Röntgenologische Messmethoden. Springer Verlag, Berlin, Göttingen, Heidelberg 1963.

BUDIN E. and CHANDLER F. Measurement of femoral neck anteversion by a direct method. Radiology 69 (1957) 209.

DOOLEY E. A., CALDWELL JR. C. W. and GLASS G. A. Roentgenography of the femoral neck technique to obtain true lateral and antero-posterior views. Amer. J. Roentgenol. 39 (1938) 834.

DUNLAP K., SHANDS JR. A. R., HOLLISTER JR. L. C. et coll. A new method for determination of torsion of the femur. J. Bone Jt Surg. 35 B (1953) 289.

DUNN D. M. Anteversion of the neck of the femur. A method of measurement. J. Bone Jt Surg. 34 B (1952) 181.

EDHOLM P. Anatomic angles determined from two radiographic projections. Acta radiol. (1966) Suppl. No. 259.

JOHNSON C. R. The measurement of the deformity of alignment accompanying fracture. Radiology 36 (1941) 100.

KINGSLEY P. C. and OLMSTEDT K. L. Study to determine angle of anteversion of the neck of the femur. J. Bone Jt Surg. 30 A (1948) 745.

LEFEBVRE J., SAUVEGRAINY J. et SAVART P. Une nouvelle méthode de mesure de l'antéversion du col fémoral. Ann. radiol. Clin. 4 (1961) 75.

LEGER W. Zur Torsionsbestimmung des Schenkelhalses. Z. Orthop. 81 (1952) 583.

MAGILLIGAN D. J. Calculation of the angle of anteversion by means of horizontal lateral roentgenography. J. Bone Jt Surg. 38 A (1956), 1231.

NORMAN O. Beskrivande geometri som hjälpmedel vid bestämning av collum anteversions och diafysvinkeln samt frakturvinkeln. (In Swedish.) Nord. Med. 73 (1965) 416 and 74 (1965) 1119.

RICHARD G. Methodik der Torsionsbestimmung mit Hilfe des Röntgenbildes. Z. Orthop. 79 (1950) 633.

ROGERS S. P. Method for determining the angle of torsion of the neck of the femur. J. Bone Jt Surg. 13 (1931) 821.

RYDER C. T. and CRANE L. Measuring femoral anteversion: the problem and a method. J. Bone Jt Surg. 35 A (1953) 321.

SCHERTLEIN A. Bestimmung des Schenkelhalstorsionswinkels vom Femur mit Hilfe von Röntgenstrahlen. Fortschr. Röntgenstr. 39 (1929) 304.

SCHULTZ P. J. Die Darstellung des Torsionswinkels vom Femur mit Hilfe von Röntgenstrahlen. Z. orthop. Chir. 44 (1923/24) 325.

TIDSTRÖM T. Anordning för bestämning av vinklar mellan axlarna hos ben i människokroppens extremiteter. (In Swedish.) Patent No. 199 927.

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ROENTGEN APPEARANCES OF ARTHRITIS OF THE HIP

by

IVAN HERMODSSON

The CE angle i.e. the angle formed by the line between C (center of the femoral head) and E (lateral margin of the acetabular fossa) and by a line drawn through C in the longitudinal axis of the body (WIBERG 1939) appears to be of fundamental importance in the roentgen diagnosis of dysplasia of the hip. This angle constitutes not only a measure of the stage of development of the acetabulum but also — and of still greater practical importance — an indicator of the distribution of the load on the joint.

Assuming that the type and severity of changes in arthrosis and arthritis are dependent largely on the distribution of load HERMODSSON (1947) analysed the appearances of coxarthrosis. All joints where the CE angle was subnormal (WIBERG) were classified as dysplastic and the type of arthrosis developing in such joints was denoted proximal arthrosis (type p), the changes being confined mainly to the proximal part of the joint with the frequently severe slipping of the head in the course of arthrosis taking place in a proximal or proximolateral direction. Arthrosis developing in joints with a normal CE angle was denoted medial arthrosis (type m). This is generally substantially less severe than the proximal type, the destruction of cartilage is confined to the medial part of the joint with the result that the joint space in the proximal part of the joint is only slightly altered. The displacement of the head, usually only insignificant, occurs in a medial or mediodistal direction.

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Table

Number of hips with arthritis in clinically verified rheumatoid arthritis

Sex	Axial type of arthritis								Changes of *proximal* type		Total *number* of joints	
	Mild form		Severe form									
	a^{+} a^{++} a^{+++}		pr		ap+pro		ap					
	No ster	Ster	No ster	Ster	No ster	Ster	No ster	Ster	No ster	Ster	No ster	Ster
Female	10	23	—	10	4	7	1	2	2	3	17	45
Male	16	13	—	1	—	8		1	2	—	18	68
Total number of joints	26	36	—	11	4	15	1	3	4	3	35	68
Total	62		11		19		4		7		103	

Symbols

Type m Coxarthrosis of medial type

Type p Proximal type of pathologic joint change (1) Coxarthrosis of proximal type (2) coxarthritis of proximal type

Type a Axial type of coxarthritis (1) a^{+} a^{++} a^{+++} = various degrees of mild form (2) ap pro ap+pro = various types of severe form ap Type a with considerable proximal displacement of femoral head pro Protrusion of arthritic etiology ap+pro Type a with combination of ap and pro

ined Normal hip joints and those exhibiting signs only of medial arthrosis were excluded A few hip joints deformed owing to epiphyseal slipping were also excluded

Cases not treated with steroids

Joints with a normal CE angle Arthritis of axial type Destruction of cartilage is the most significant and decisive roentgenographic sign of coxarthritis Such destruction in joints with a normal CE angle is observed both proximally and medially Proximally the destruction of cartilage is reflected by diminished joint space In the medial part of the hip joint no joint space is evident but cartilage destruction is demonstrable as a diminution in the caput fossa distance This distance has been defined in 1947 by the author as the shortest distance between the medial contour of the head and the outer side of the U figure This type of cartilage destruction implies displacement of the femoral head relative to the acetabulum in a craniomedial direction i e largely in the direction of the axis of the femoral neck This is the reason for the terms cartilage destruction of axial type and arthritis of axial type (type a in the Table) The diminution in

Observations made by the author in 1947 provided a basis for forming a concept of the roentgen appearance of coxarthrosis in normally developed and in dysplastic joints thereby facilitating the differentiation between arthrosis and arthritis. This publication was followed (1948) by an investigation on the hip joints in patients with a well established clinical diagnosis of rheumatoid arthritis. Normally developed hip joints offered no difficulties in the recognition of arthrosis (medial type). The destruction of cartilage in some other conditions was confined to the upper and medial parts of the joint with craniomedial displacement of the femoral head, i.e. roughly in the same direction as the axis of the femoral neck. This type of change was therefore called axial (type a) and considered a sign of rheumatoid arthritis. As for dysplastic hip joints, the changes were always of the proximal type so that it was difficult or impossible to differentiate between arthrosis and arthritis. The publications on arthrosis by the author (1947, 1970) and arthritis of the hips (1948) appear to have passed almost unnoticed in the literature. Neither has the importance of the CE angle in the diagnosis of these conditions received the attention it would appear to deserve. The present paper constitutes a further approach to coxarthritis in clinically verified rheumatoid arthritis as well as in tuberculous coxitis of the synovial type.

As for the roentgen technique suffice it to mention that both a.p. and lateral views of the femora were always obtained, and that both projections included the entire pelvis.

A.p. views provide: (1) A rough estimation of the mineral content of the bone. (2) Evaluation of the CE angle. (3) Comparable roentgenograms of the so called U figure (tear figure) and thereby the determination of the thickness of the cartilage. (4) Evaluation of the acetabular fossa and the degree of protrusion, if any.

The lateral views provide: (1) Complementary evaluation of the anatomy of the femoral head and neck and exclusion of any sequelae following epiphyseal slipping. (2) Careful evaluation of any osteophytes in the hip particularly capital drop and buttress (WIBERG). (3) Evaluation of the deformation of the head caused by necrosis and collapse in arthrosis and arthritis.

Roentgen appearances of rheumatoid arthritis

It should be stressed that even in patients with an established clinical diagnosis of rheumatoid arthritis not all of the pathologic changes are of an arthritic nature. It is important also to decide upon the significance of steroid treatment as a contributory cause of arthritis since opinions upon this still differ.

Roentgenograms of the hip joints of all patients with clinically verified rheumatoid arthritis referred to the roentgen department in 1968 were exam

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The lateral views provide (1) Complementary evaluation of the anatomy of the femoral head and neck and exclusion of any sequelae following epiphyseal slipping (2) Careful evaluation of any osteophytes in the hip particularly capital drop and buttress (WIBERG) (3) Evaluation of the deformation of the head caused by necrosis and collapse in arthrosis and arthritis

Roentgen appearances of rheumatoid arthritis

It should be stressed that even in patients with an established clinical diagnosis of rheumatoid arthritis not all of the pathologic changes are of an arthritic nature It is important also to decide upon the significance of steroid treatment as a contributory cause of arthritis since opinions upon this still differ

Roentgenograms of the hip joints of all patients with clinically verified rheumatoid arthritis referred to the roentgen department in 1968 were exam

medial arthrosis in which the diminution of the joint space is limited to the most medial part and is never severe In the first and mildest stage it may, however, be difficult to make a clear distinction between axial and medial destruction of the joint cartilage and consequently between arthritis and arthrosis This is especially true if the outline of the acetabulum be irregular in shape The articular outline the cortex of the femoral head consisting mainly of the basal calcified zone in the joint cartilage is rarified in arthritis and may exhibit more or less severe defects The articular outline then becomes blurred and unevenly eroded Owing to the anatomy of the hip joint, however the cortical changes usually present no early signs and are not demonstrable before the diminution in the joint space has appeared

Differentiation between early arthritis and arthrosis is facilitated by the presence or absence of osteophytes Osteophytes are missing in incipient arthritis although it is true that arthritis may develop in a joint already involved by mild medial arthrosis and may make an early differential diagnosis difficult Osteophytes appear early however in medial arthrosis and careful examination of cases of early medial arthrosis exhibiting signs of cartilage destruction will nearly always reveal osteophytes Osteophytes are generally missing even in advanced cases of axial arthritis although marginal osteophytes may sometimes be observed It should, however be stressed that osteophytes do not make a differential diagnosis impossible, because the cartilage destruction of the axial type indicates arthritis

The calcium content in the region of the hip joint and throughout the pelvis is often decreased in arthritis although this varies widely It should be borne in mind that a roentgen examination is not the most effective method of diagnosing a decrease of the calcium content in bone In early arthritis the calcium content at one examination may appear slightly decreased but normal at a later examination This may have to do with the undulatory activity of the rheumatoid process and with a change or discontinuation of the steroid treatment If the structure of the cancellous bone be preserved and be clear and distinct despite the decreased calcium content this decrease may be regarded as a manifestation of osteoporosis This rarefaction of bone is of less significance in the roentgen diagnosis of rheumatoid coxarthritis than in arthritis elsewhere in the body

The cancellous structure is blurred or missing in some areas exhibiting a decreased calcium content As will later be discussed aseptic necroses no doubt exist in such areas Opinions differ on the nature and occurrence of those osseous changes in arthritis of the hip This is largely because of the general absence of pathologic examination of the bone structures explored at operation or post mortem and applies in particular to the bone tissue around the acetabulum

The best contribution in the literature on these matters is probably that

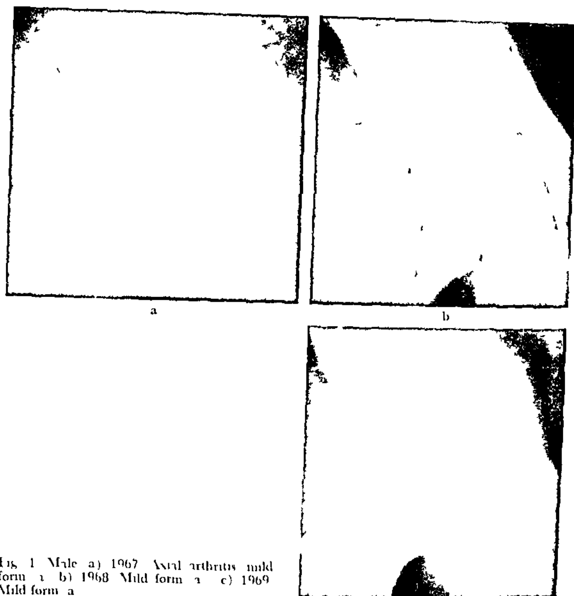


Fig. 1. Male. a) 1967. Axial arthritis, mild form a. b) 1968. Mild form a. c) 1969. Mild form a.

the joint space is therefore most marked medially. The lateral part of the joint space in mild conditions may, owing to the medial shift of the femoral head, escape a decrease in width. The ensuing wedge shape of the joint space, commonly evident in joints with axial destruction of the cartilage, is characteristic and often more easily recognized than slight diminution of the joint space as a whole.

If the arthritis be fairly advanced, the axial type of cartilage destruction is characteristic and readily recognized (Fig. 1). It is also easily distinguished from



Fig 2 Female a) 1967 Axial arthritis mild form a b) 1970 Severe form ap + pro

Only 3 patients had the severe form of axial arthritis in the present material not treated with steroids and consisting of 31 joints (1) A female patient had marked unilateral destruction of the bone above the acetabulum and protrusion type ap + pro) (2) Another female patient had changes of type ap + pro in one hip joint with changes of type ap on the other side (thus no protrusion) Both women were postmenopausal at the time of onset of rheumatoid arthritis (3) Changes of the type ap + pro were evident in both joints in a female patient in whom severe rheumatoid arthritis had developed at 23 years of age At the first roentgen examination the acetabulum was thin and deep but without any secondary changes Roentgen examination of the hands and feet revealed signs of mutilating arthritis (Fig 2)

The series of patients of HERMODSSON (1948) not treated with steroids included only a few with isolated protrusion (all of them postmenopausal women) and furthermore there were changes of type ap + pro in two elderly female patients with severe rheumatoid arthritis in whom joint lesions in the hands and feet had the character of mutilating arthritis (severe doigts en lorgnette)

None of the males not treated with steroids had arthritis of a severe type in 1943 nor in 1968

These observations are in accord with the above statement that the severe forms of axial arthritis are not part of rheumatoid arthritis provided steroids

published by RUTISHAUSER & JACQUELINE (1964). Unfortunately, however, it is not clearly stated whether their patients had been treated with steroids or not.

It should be stressed that the osseous changes in cases not treated with steroids are usually only mild or moderate. Extensive changes with destruction of the femoral head and the bone around the acetabular fossa are not ordinary features of axial arthritis unless the patient has received steroid treatment. The osseous changes usually affect the femoral head and the acetabulum largely to the same degree. In the grading of the material into severe and mild cases particular attention was paid to the changes around and above the acetabulum. Arthritis was considered severe if considerable proximal displacement of the femoral head, more or less deformed and diminished by the osseous changes, into the pelvic bone above the acetabulum was evident. Such cases are designated type "ap" in the Table. The substantial proximal displacement is usually combined with protrusio acetabuli of arthritic etiology. Cases of protrusion only — thus without any considerable bone destructions above the acetabular fossa — were classified as severe.

Protrusio acetabuli is still somewhat obscure. Three roentgenographic types may be distinguished. (1) Primary protrusion, 'Otto Chrobak's pelvis'. The base is thin, fine and regular. Protrusions into the pelvis lie at the same level as the acetabular fossa. The condition is usually bilateral and symmetric. (2) Protrusion secondary to medial coxarthrosis. The base is more or less irregularly thickened. The protrusion into the pelvis is at the same level as the fossa or somewhat lower because of the medial type of cartilage destruction which owing to the anatomy of the joint may result in distal displacement of the femoral head relative to the fossa (HERMODSSON 1970). (3) Protrusion secondary to axial arthritis. The protrusion into the pelvis lies higher than the acetabular fossa because of the proximal displacement of the femoral head by the axial cartilage destruction. If the arthritis has caused extensive bone destructions above the level of the acetabulum with ensuing considerable proximodorsal displacement of the femoral head, the protrusion into the pelvis usually extends far above the fossa. The cortex of the fossa is usually uneven in thickness, often thin and in some areas defective. In other cases it is markedly thickened and irregular. In the former the appearances reflect a more or less active process, in the latter there is a healing tendency or a repair stage. A more distinct and wider joint space between the femoral outline and the wall of the protrusion is also often evident in the latter. It is possible in the course of rheumatoid arthritis to follow the gradual development of a protrusion from the normal.

The most marked protrusion into the pelvis occurs in those cases of rheumatoid arthritis in which the protrusion is combined with severe destruction above the acetabulum.

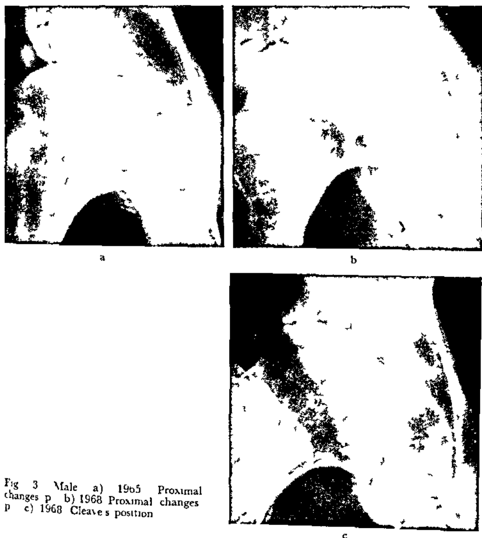


Fig 3 Male a) 1965 Proximal changes p b) 1968 Proximal changes p c) 1968 Cleave s position

Cases treated with steroids

Joints with a normal CE angle Arthritis of axial type It is now generally accepted that steroid therapy of rheumatoid arthritis may have an unfavourable effect on the joints This applies especially to weight bearing joints and is believed to be due to the propensity of steroids to demineralize bone and so weaken its resistance It was therefore decided to grade the present material into two groups according to whether the patients had received steroid treatment or not

have not been given. This still holds true despite the usage of drugs not related to steroids, which by palliation of the symptoms and signs allow the patient to use and load his hip joints much more than was previously possible (so called relative hyperfunction).

Joints with a subnormal CL angle. Changes of proximal type. While inflammation of joints with a normal CL angle exhibits an axial type of pathognomonic changes, the situation is quite different in dysplastic joints with an abnormally small CL angle. It is not possible to demonstrate any type of roentgen changes pathognomonic of arthritis in joints with a subnormal CL angle. This was pointed out by the author in 1948 and corroborated in the present investigation. Joints with a subnormal CL angle develop only one type of change, namely that described as proximal (type p) (HERMODSSON 1970).

Cartilage destruction of the proximal type is demonstrable as a narrowing of the joint space, especially laterally. Owing to the destruction of the cartilage the femoral head is displaced craniolaterally and the caput fossa distance is increased. The osseous changes are confined to the area around the most involved part of the cartilage, and most marked in the upper and lateral part of the femoral head and lateral part of the acetabulum, particularly the area inside L; point L may therefore gradually be difficult or impossible to define in the roentgenogram. (In the strict sense no point L exists.)

The osseous changes may result in a collapse of considerable portions of bone, both in the femoral head and in the region above the acetabulum. The ensuing displacement of the head may be much greater than that caused by the cartilage destruction. As a consequence of the displacement of the head, which is usually reflected by an increase in the caput fossa distance and interruption of the so called 'Shenton's line', a 'double acetabular floor' and a 'capital drop' gradually forms. Where the CL angle is subnormal it is thus impossible to differentiate with certainty between inflammatory and degenerative conditions by roentgen examination alone. Clinical data in such cases may suggest the presence or absence of arthritis. Osseous changes that have progressed rapidly and are marked may point to arthritis particularly in a young patient. If the contralateral hip joint be normally developed and exhibit signs of axial arthritis it is possible that the changes in the dysplastic joint are also manifestations of arthritis.

The present material included four hip joints with proximal changes in patients not treated with steroids, and in view of the observations set forth all four probably had arthritis. In two of the joints the proximal changes were severe with a large increase in caput fossa distance at the last roentgen examination, yet neither a double floor nor a capital drop was demonstrable. Such exceptional appearances may possibly be regarded as indicating arthritis (Fig. 3).

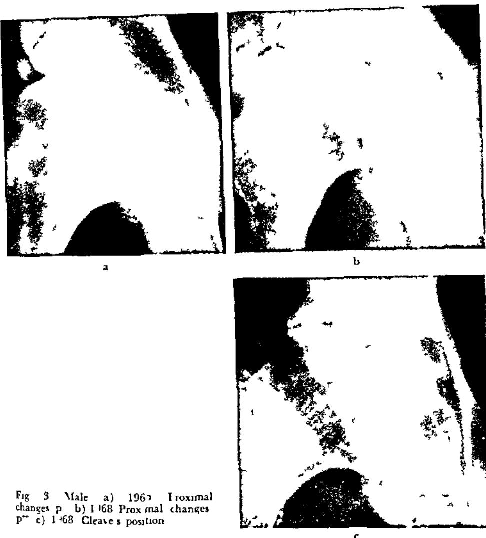


Fig 3 Male a) 1963 Proximal changes p b) 1968 Proximal changes p++ c) 1968 Cleaves position

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Fig 4 Male a) 1965 Axial arthritis mild form a b) 1969 Severe form ap + pro



Fig 5 Male a) 1957 Axial arthritis mild form a b) 1968 Severe form ap + pro

mode of development of the severe forms of axial arthritis explains why they occur relatively late sometimes not until the actual inflammatory process has abated or become quiescent and often long after the discontinuation of steroid treatment

Further, since weight bearing is of considerable significance in causing changes in patients treated with steroids, grading of the material into joints with normal weight bearing and joints with abnormal weight bearing, as judged from the size of the CE angle, must be of fundamental importance in the evaluation of the steroid treatment

A search of the literature failed to reveal any investigation of this type This has made it more difficult to judge the unfavourable effects of steroid treatment in the cases published The literature contains reports of hip joints with proximal changes described by the respective authors as examples of rheumatoid arthritis influenced by steroid therapy, though it may be that the changes represented proximal arthrosis in rheumatoid patients

The early course of rheumatoid arthritis is largely the same whether the patients are treated with steroids or not The effect of steroids becomes apparent *when the destruction of the cartilage is subtotal or total* By that time the rheumatoid process has weakened the bony tissue both in the bone around the acetabulum and in the femoral head by demineralization, presumably because of increased bone resorption Steroids will accentuate the weakening of the bone by osteoporosis, interpreted as resulting from decreased bone formation

When the arthritic process had reached this stage, the osseous parts of the joint are in contiguous contact and consequently are not protected by any intermediate elastic cartilage The above changes further the arising of osseous changes that must be regarded as aseptic bone necroses That steroids can produce aseptic bone necroses in the hip joint has been demonstrated and well documented by reports of so called bone infarction with avascular necrosis of the femoral head in a previously normal hip joint following steroid treatment (Because of skin disease, for example cf KLUMPLER et coll 1967, WERNE 1962)

The osseous changes in the pelvis due to rheumatoid arthritis treated with steroids may involve areas away from the acetabulum The *calcium content* is decreased and the disappearance of cancellous structure in discrete areas leaves the impression of cyst like formations Adjacent to the acetabulum are large bone defects in which the similarly changed femoral head is wedged in frequently by marked proximal displacement In some areas close to these bone defects the calcium content is increased relative to normal cancellous tissue but the structure is absent The functional demands of weight bearing causes relative overloading of those parts of the bone weakened by *osteoporosis* especially in the region of the center of the acetabulum This results in fractures of the cancellous trabeculae and necrosis and collapse of bone The *accumulation* of closely packed, unresorbed bone debris may possibly be misinterpreted as co existing osteosclerosis Characteristic appearances are produced by these changes around the acetabulum and the proximal displacement of the femoral head The

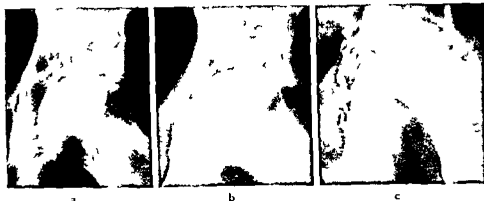


Fig Female a) 1966 Small cyst in the pelvis b) 1967 Axial arthritis mild form a c) 1970 Severe form ap + pro

Case 3 Female with rheumatoid arthritis from 1959 had been treated with steroids since 1961 Roentgen examination of the right hip in 1966 demonstrated partly undefined cyst like destruction of the acetabulum associated with a small defect in the outline of the joint Mild axial arthritis developed the following year (Fig 7)

The unfavourable side effects of steroid therapy in rheumatoid coxarthritis are obvious Steroid therapy was prescribed largely during the 1950s and the beginning of the 1960s and was almost always systemic and not local Caution should of course be exercised in evaluation of the findings in a relatively small series but such consideration is at any rate of interest since similar investigations are difficult to find in the literature

The entire material included the severe types of axial arthritis (ap ap + pro pro (1) Patients *not treated with steroids 5 out of 31 joints (16 per cent)* affected (2) Patients treated with steroids 29 out of 65 joints (45 per cent) affected

Five of the 29 joints with severe arthritis treated with steroids had no abnormal signs at the first roentgen examination and 18 joints presented only mild changes Five joints were not examined roentgenologically at the onset of steroid therapy but 5 years or more later presented evidence of marked arthritis. It must therefore be assumed that the arthritis was only slight at the onset of the steroid therapy Finally one patient had been treated with steroids for more than a year when the arthritis was demonstrated Arthritis has thus never been proved as severe before or at the onset of steroid therapy Treatment of 17 of the 29 *joints with a severe form of arthritis* with steroids had even discontinued before the condition had fully developed Eighteen of the 26 joints of the patients who developed protrusion (both pro and ap + pro) had been under steroid

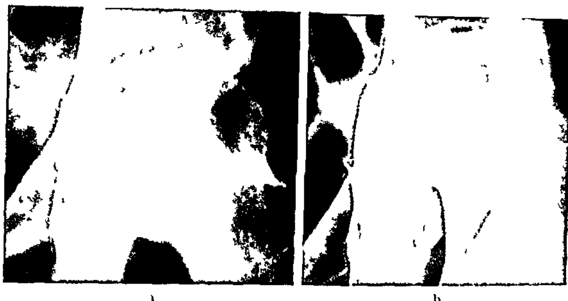


Fig 6 Female a) 1962 Large cyst in head and neck b) 1968 Axial arthritis severe form ap + pro

As in the early stages of axial arthritis proximal displacement of the femoral head is usually associated with medial displacement resulting in protrusio acetabuli, frequently marked (Fig 4) Isolated protrusion may develop in the course of axial arthritis, with little destruction of the bone above the acetabulum or proximal displacement of the femoral head such conditions occur exclusively in females This distribution differs entirely from that in severe arthritis of the type 'ap + pro', in which there is no relationship to sex (see Table)

The osseous changes in the femoral head may often result in collapse and ensuing resorption of areas, most of the femoral head may even have disappeared (Fig 5)

The three following patients with axial arthritis had undergone steroid treatment before any changes had developed

Case 1 Female with rheumatoid arthritis since 1955 had been treated with steroids during the period 1959—1962 Roentgen examination of the right hip joint in 1962 revealed a large cyst in the lateral upper part of the femoral neck and adjacent part of the head as well as areas of necrosis (rarefaction and blurred structure) in its medial aspect No signs of arthritis were present until 1968 (Fig 6) (type ap + pro)

Case 2 Male with rheumatoid arthritis since 1948 had been treated with steroids during the period 1963—1965 Roentgen examination in 1965 disclosed a large cyst with a fracture through its lateral wall in the lateral upper part of the left femoral neck The following year the cyst had decreased in size and had been obliterated by bone the fracture had healed Mild axial arthritis developed in 1965



Fig 9 Male Tuberculosis Axial arthritis mild form a



a



b

Fig 10 Female a) 1937 Tuberculosis Axial arthritis mild form a b) 1940 Severe form ap + pro

if the rheumatoid arthritis be treated with steroids This is also obvious from the examination of young patients in whom nothing to suggest primary cox arthrosis exists It may therefore be assumed that proximal changes in two of the three joints in the present material were associated with arthritis the patients were females Bony ankylosis was not observed in any patient of the present material

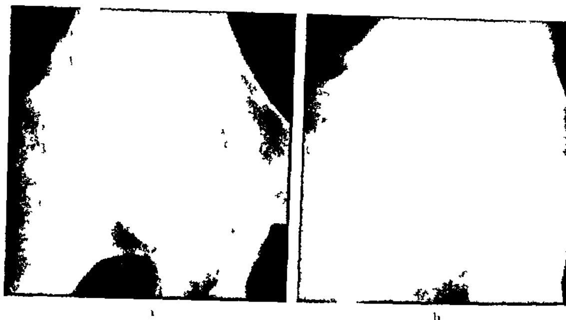


Fig. 8. Female. a) 1965. Proximal changes, p. b) 1969. Proximal changes, p.

treatment for 5 years or more before this was demonstrated. Twenty four of these 26 joints belonged to patients who were 40 years of age or more when the protrusion was demonstrated.

Steroid therapy is usually given not for arthritis but because the rheumatoid disease causes such severe symptoms that palliation with steroids is indicated. This principle was applied in the present material. Steroid treatment in most or probably all patients was thus started when the coxarthritis was in the mild stage or when the appearances of the hip were normal. The severe types of coxarthritis developed mainly in patients treated with steroids (29/34). Arthritis was never severe in the hips of males not treated with steroids. A previous series of patients with rheumatoid arthritis reported by the author in 1948 (thus before the steroid era), included only a few with arthritis associated with marked osseous changes. All these facts suggest that steroid therapy frequently causes arthritis of the hip to become severe.

Joints with subnormal CE angle. Changes of proximal type. As already mentioned above, the roentgen appearances of rheumatoid arthritis of the hip with a subnormal CE angle are essentially the same as those present in proximal arthrosis. The changes may progress more rapidly in arthritis and the osseous changes may become more severe, but it is usually impossible to arrive at a differential diagnosis (Fig. 8).

This acceleration and aggravation of the changes in arthritis compared with those in arthrosis increases still more, especially as regards the osseous changes,

ZUSAMMENFASSUNG

Die Bedeutung des CE-Winkels als Erscheinungsbild einer rheumatoiden Arthritis der Hüfte wird in einem Material von 31 nicht mit Steroiden behandelten Patienten und 65 Patienten denen eine solche Behandlung gegeben war diskutiert. Die Belastung des Gelenks hat eine entscheidende Bedeutung für die Form der Arthritis: axial bei normalen Gelenken, proximal bei dysplastischen. Die häufig ungünstige Wirkung der Steroiden auf die Entwicklung dieses Zustands wird betont. Die tuberkulöse Synovitis kann ein ähnliches Erscheinungsbild verursachen.

RÉSUMÉ

L'auteur étudie l'intérêt de l'angle CE pour l'examen des arthrites rhumatismales de la hanche dans une série de 31 patients qui n'ont pas été traités par les stéroïdes et de 65 patients qui ont subi ce traitement. L'effort supporté par cette articulation joue un rôle important sur le type d'arthrite: axiale dans les articulations normales, proximale dans les articulations dysplasiques. L'auteur insiste sur l'effet souvent défavorable des stéroïdes sur l'apparition de cette affection. La synovite tuberculeuse peut donner des aspects semblables.

REFERENCES

ETTER, H.: Entzündliche Gelenkerkrankungen. *In*: Encyclopedia of medical radiology, Volume 3, p. 512. Springer, Heidelberg 1968.

HERMODSSON, I.: On the roentgenologic appearance of osteo-arthrosis deformans in the hip joint. Acta radiol. (1947) Suppl. No. 66.

— The roentgen picture of osteo-arthritis in the hip joint in cases of polyarthritis rheumatica chronica. Acta radiol. 29 (1948), 139.

— Roentgen appearance of coxarthrosis. Acta orthop. scand. 41 (1970), 169.

KLÜMPER, A., LOHMANN, W., LEHLINGER, L., WELLER, S. und STREY, M.: Aseptische Knochennekrosen des Oberschenkelkopfes nach Glucocorticoidbehandlung. Fortschr. Röntgenstr. 107 (1967), 96.

RUTISHAUSER, E. and JACQUELINE, F.: Involvement of the hip in ankylosing spondylitis and rheumatoid arthritis. Doc. Geigy No. 16. Basel 1964.

WERNE, S.: Compression fracture of the femoral head in association with cortisone therapy. Acta orthop. scand. 32 (1962), 413.

WIBERG, G.: Studies on dysplastic acetabula and congenital subluxation of the hip joint. Acta chir. scand. 83, Suppl. 58, 1939.

Roentgen appearances of tuberculous coxitis

The rarity today of tuberculous coxitis in Sweden has rendered it impossible to collect any large material. Moreover films of patients examined before the appearance of osseous destruction are not often available. They were either not obtained or were stored only exceptionally. The author has however had the opportunity of examining the files of a sanatorium for bone and joint tuberculosis. These contained films of tuberculous coxitis dating back to the beginning of the 1930s and would appear to justify the following conclusions. Two types of tuberculous coxitis, primary osteitis and primary synovitis, may be recognized roentgenologically. Primary osteitis is of no relevant interest because the location of the osseous lesions is the dominating feature. Primary synovitis is, however, important because the roentgen appearances may be compared with those in rheumatoid arthritis, which is also primary synovitis with secondary osseous changes. Coxitis of the primary synovitis type in dysplastic hip joints assumes proximal forms essentially the same as those in rheumatoid arthritis in such joints. The destruction of cartilage is thus most marked in the proximolateral part of the joint and the femoral head is displaced outwards and cranially.

Of greatest interest, however, is the appearance of coxitis in normally developed joints, i.e. with a normal CE angle. Coxitis of the type primary synovitis in such joints causes an axial type of arthritis of essentially the same roentgen appearances as in rheumatoid arthritis. Destruction of cartilage is thus most marked in the craniomedial part of the joint and the displacement of the femoral head takes place in the same direction, that is largely along the axis of the femoral neck. The osseous changes in the hip closely resemble those in rheumatoid arthritis, especially of the severe forms in patients treated with steroids. This applies also to the appearances of the protrusion, which is relatively common in tuberculous coxitis. It may sometimes even be difficult to differentiate between tuberculous coxitis and rheumatoid arthritis. This fact is also emphasized and illustrated in the literature (LITTLE 1968) (Figs 9, 10).

The distribution of load on the hip joint, as judged from the size of the CE angle, is thus, even in tuberculous coxitis, of decisive importance in the type of arthritis appearing in primary synovitis.

SUMMARY

The significance of the CE angle for the appearances of rheumatoid arthritis of the hip is discussed in a material of 31 patients not treated with steroids and 65 patients given such treatment. The load on the joint plays a dominant role for the type of arthritis: axial in normal joints, proximal in dysplastic joints. The frequently adverse effect of steroids upon the development of the condition is stressed. Tuberculous synovitis may cause similar appearances.

Materials and Methods

Subacute toxicity in rats Sixty Wistar albino rats averaging 250 g were divided into three groups of 20 rats each (10 males and 10 females), one group serving as an untreated control group Another group was treated with 500 mg/kg daily of the test product and the third group with 1 000 mg/kg daily The B 8890 in the form of a solution of the sodium salt was administered by gavage in a single daily dose

Each animal was treated 5 days a week for 4 weeks. During treatment the animals housed in cages containing 5 rats each were constantly watched for evidence of toxic symptoms each animal was weighed once a week At the end of treatment each animal was given laboratory tests including urinalysis hemochromometry and blood cytology assay of blood urea nitrogen (BUN) (FAWCETT & SCOTT 1960) blood glucose (HÄRTEL et coll 1969), bilirubin (JENDRASSIK & GROF 1938) serum proteins glutamic pyruvic and glutamic oxalacetic transaminases (SGPT SGOT BERGMEYER 1962) serum aldolase (BERGMEYER 1962) and serum alkaline phosphatase (BESSEY et coll 1946) Eight animals per group (4 males and 4 females) were tested for liver functional capacity by calculation of the half time (t) of plasma levels of bromsulphalein (BSP) 50 mg/kg of the dye Bromthalein Merck being administered intravenously

All the animals were killed by exsanguination and subjected to autopsy the principal organs from each animal were weighed while fresh then prepared for microscopy by fixation in Bouin s fluid paraffin inclusion and staining with hematoxylin eosin

Subacute toxicity in dogs Eighteen beagles about 5 months of age (9 males and 9 females) were divided into 3 groups of 6 animals each Again, one group was set aside as control one was treated with 200 mg/kg B 8890 daily and the third group with 800 mg/kg daily administered orally in the form of free acid enclosed in hard gelatin capsules. Since preliminary tests had disclosed that 800 mg/kg had a certain tendency to cause vomiting, this was divided into two separate doses each day

The dogs were watched throughout for toxic manifestations their food consumption was measured daily and each animal was weighed at 7 day intervals At the end of treatment each dog was given the same laboratory test as previously listed the BSP blood kinetics were calculated after the intravenous administration of 12 5 mg/kg Bromthalein Merck

Finally the animals were killed by exsanguination under sodium pentobarbital anesthesia and subjected to autopsy The heart spleen, kidneys liver, thyroid and adrenal glands from each animal were weighed *while fresh and*

FROM THE RESEARCH LABORATORIES OF BRACCO INDUSTRIA CHIMICA S.P.A., MILAN, ITALY

INVESTIGATION OF THE TOXICOLOGY OF A NEW ORAL CONTRAST MEDIUM FOR CHOLECYSTOGRAPHY

by

G. ROSATI, P. DE MICHELI and P. SCHIANTARELLI

The oral contrast media employed in cholecystography to date have left a good deal to be desired. The appearance of a new substance must therefore arouse considerable interest from all aspects but particularly as regards toxicity.

2-{2-[3-(N-ethyl-acetamido)-2,4,6-triiodophenoxy]-ethoxy}-propionic acid, coded B 8890, has proved markedly bilitropic in rabbits, cats, rats, and dogs; it has exhibited more favourable characteristics than iopanoic acid and ipodate, being less toxic and better absorbed in the intestine (ROSATI, et coll. 1972). It was decided that before the new product could be recommended for clinical use in human subjects the range of safe dosage had to be determined by means of subacute toxicity investigations in the rat and dog.

The kidney is also involved in toxic effects from oral contrast media for cholecystography and the action of B 8890 on renal function was therefore also investigated by its direct introduction into the renal circulation.

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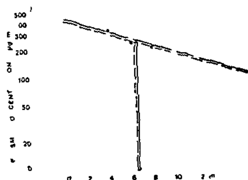


Fig 2 Determination of 1½ of BSI plasma levels in rats ●——● group 1 (controls) O — — — O group 3 (1 000 mg/kg daily)

aldolase and alkaline phosphatase Rats treated with 1 000 mg/kg daily had a loss of body weight in the first week of the experiment during the ensuing weeks however the body growth curve of these animals was similar to that of the controls (Fig 1) Again the higher dosage of B 8890 produced an increase in the total blood bilirubin in males and females alike only in the males was an increase of BUN of about 24 per cent compared to the controls recorded (Table 1) No alteration in the capacity of the liver for clearing BSP was evident in either dosage group (Fig 2)

The weights of the liver and thyroid were greater than the control values in both treatment groups

Microscopy of the liver revealed no changes in animals treated with 500 mg/kg B 8890 daily in those receiving 1 000 mg/kg daily however several instances of hepatocyte swelling with an acidophilic cytoplasm from loss of basophilic bodies were observed A detachment of cell elements of the laminae was also evident in some preparations Changes in the thyroid glands indicated functional hyperactivity the follicles were of various sizes and dilated with

Table 1

Blood urea nitrogen (BUN) and total bilirubin in rat blood serum (mg/100 ml) Mean values ± SE

B 8890 (mg kg daily)	Males		Females	
	BUN	Bilirubin	BUN	Bilirubin
0	54±2 13	0 14±0 004	68±7 2	0 14±0 00
00	57±1 37	0 14±0 004	58±6 1	0 14±0 00
1 000	66±1 20	0 40±0 004	52±2 9	0 40±0 12

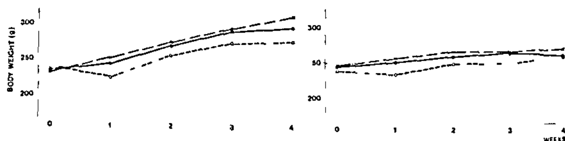


Fig. 1. Influence of the administration on the body weight of rats (males to the left, females to the right). ●———● group 1 (controls); ×— —× group 2 (500 mg/kg daily); O– – –O group 3 (1 000 mg/kg daily).

prepared for microscopy by fixation in formalin, paraffin inclusion, and staining with hematoxylin eosin. The microscopy was extended to parts of the stomach, ileum, colon and gallbladder.

Action on renal function. The renal toxicity of B 8890 was compared to that of iopanoic acid by an experimental procedure involving their injection through the renal artery directly into the kidney.

Rabbits were anesthetized with barbiturates and the segment of the abdominal aorta corresponding to origins of the renal arteries prepared; each ureter was also prepared with catheters for the collection of urine separately from each kidney. As the right and left renal arteries arise from the aorta at different levels, it is possible to introduce the contrast medium to each kidney separately by applying arterial clamps to the aorta immediately above and below the origin of the relative artery and injecting the contrast medium into the aorta between the two clamps (IDBOHRN & BERG 1954). Both contrast media, B 8890 and iopanoic acid, were injected as sodium salt solutions of varying strength in a standard amount of 1 ml and a standard time of 5 s through the aortic wall; the complete procedure involved the arrest of the renal circulation for 10 s. One hour after the injection the functional capacity of the right (control) kidney and the left (treated) kidney were assessed separately by evaluation of the creatinine and para-aminohippuric acid clearance.

Creatinine, 25 g of which were administered subcutaneously to each animal, was assayed by the method of LANGLEY & EVANS (1936); PAH acid, 200 mg/kg given subcutaneously, was assayed by the method of BRATTON & MARSHALL (1939).

Results

Subacute toxicity in rats. Treatment with B 8890, both in amounts of 500 mg/kg and 1 000 mg/kg daily, produced no changes in behaviour, the urinalysis or hematologic findings, or the plasma levels of glucose, proteins, SGPT, SGOT,

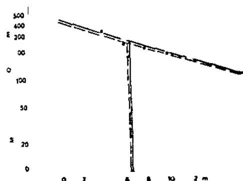


Fig 2 Determination of the BSP plasma levels in rats ● — — ● group 1 (controls) ○ — ○ group 3 (1 000 mg/kg daily)

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The weights of the liver and thyroid were greater than the control values in both treatment groups

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Blood urea nitrogen (BUN) and total bilirubin in rat blood serum (mg 100 ml) Mean values ± SE

B 8890 (mg kg daily)	Males		Females	
	BUN	Bilirubin	BUN	Bilirubin
0	4 ± 2 13	0 14 ± 0 004	68 ± 7 2	0 14 ± 0 00
00	57 ± 1 37	0 14 ± 0 004	58 ± 6 1	0 14 ± 0 00
1 000	66 ± 1 20	0 40 ± 0 004	57 ± 2 9	0 40 ± 0 12

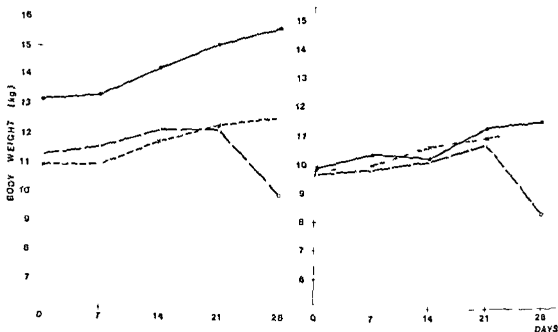


Fig 3 Influence of the administration on the body weight of male (left) and female (right) dogs ●——● controls × —— × 200 mg/kg daily ○— — —○ 800 mg/kg daily

scant fluid colloid, which was vacuolar and typically festooned, the lining epithelium was columnar, basophilic and thickened These alterations were slight in the group of animals treated with 500 mg/kg daily but more marked in those receiving 1 000 mg/kg daily

All the other organs were noncontributory

Subacute toxicity in dogs A dose of 200 mg/kg B 8890 daily was well tolerated, none of the animals so treated presented any differences from the controls, either clinically or in terms of laboratory findings In contradistinction the test product caused certain side effects at the dosage level of 800 mg/kg daily Fifteen instances of vomiting throughout the experimental period were recorded in the two cages containing the animals of this dosage group, loose stools were not uncommon

Some loss of body weight in these animals occurred during the last week of treatment, with final weights 12 to 14 per cent less than initially (Fig 3) Associated with the loss of body weight was a reduction in the consumption of food, the animals in this dosage group consumed a total of 11 3 kg of food, as against 23 5 kg in the same time by untreated controls Compared to the latter, the male dogs treated with 800 mg/kg B 8890 daily presented higher levels of BUN and alkaline phosphatase (Table 2) and greater weight of the liver and thyroid, the female dogs in the same dosage group differed from the untreated

Table 2

Blood chemistry and bromosulphalein (BSP) disappearance in the dogs The values are the means of 5 experiments

B 8890 (mg kg daily)	Sex	BUN (mg/100 ml)	Glucose (mg/100 ml)	Total bilirubin (mg/100 ml)	Total proteins (g/100 ml)	SGOT (mU/ml)	SGPT (mU/ml)	Aldolase (mU/ml)	Alcaline phosphatase (mU/ml)	BSP t (s)
0	M	8.8	94	0.52	5.47	13.0	12.0	4.0	39	487
200	M	9.6	98	0.18	5.42	10.6	14.2	6.2	46	635
800	M	26.3	112	0.20	5.56	10.9	7.1	4.6	63*	430
0	F	9.8	100	0.35	5.58	13.2	12.2	4.8	50	670
200	F	10.5	111	0.17	5.32	11.0	14.5	6.5	48	470
800	F	13.9	104	0.12	5.15	10.9	10.6	5.6	62	380

* *Statistical significance of the difference from control* $p < 0.05$

controls only in terms of liver and thyroid weights, the BUN and alkaline phosphatase were unaltered

The counterpart of the increased liver weight was a swelling of the liver cells particularly those in a central lobular position with a loss of basophilic bodies

The thyroids presented evidence of partially dilated follicles with cubical cells light cytoplasm and poorly staining vacuolar colloid The kidneys had alterations of little import such as swelling of a few cells in the proximal convoluted tubules this was observed in male and female dogs alike

Action on renal function (Table 3) B 8890 proved markedly less toxic than iopanoic acid to the kidneys of rabbits the new compound produced practically no change in renal function in a concentration of 0.25 per cent, whereas the same concentration of iopanoic acid caused an impairment of renal function of about 80 per cent At higher concentrations B 8890 reduced the functional capacity of the treated kidney by no more than 30 per cent compared to the contralateral (control) kidney iopanoic acid however produced almost complete inhibition of creatinine and PAH acid clearances

Discussion

The new oral contrast medium for cholecystography B 8890 is recommended for clinical use in man in a dosage of 3 g which means 50 mg/kg in a subject weighing 60 kg furthermore the product is usually administered only once

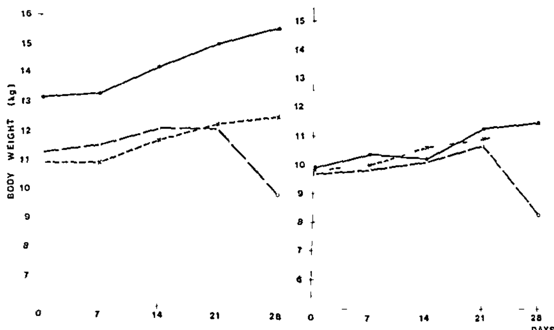


Fig 3 Influence of the administration on the body weight of male (left) and female (right) dogs ●——● controls ×– – –× 200 mg/kg daily ○— – –○ 800 mg/kg daily

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noncontributory The new compound, injected directly into the renal circulation in rabbits proved much less nephrotoxic than iopanoic acid, this being the oral contrast medium for cholecystography best established and extensively used

Rats treated with both dosage levels of B 8890, and dogs receiving 800 mg/kg of the product daily presented a significant increase in thyroid weight relative to untreated controls, together with histologic evidence of functional hyper activity of the gland On the other hand, this phenomenon was not observed in dogs treated 20 times during a period of 4 weeks with doses four times the human dose At the dosage level of 800 mg/kg daily, B 8890 produced side effects involving the gastrointestinal tract of dogs frequent episodes of vomiting and diarrhea occurred and in the last week of treatment the animals consumed about half the food eaten by the untreated controls and lost weight accordingly

It would appear that the experiments have established that the new oral contrast medium for cholecystography B 8890 offers a wide margin of safety relative to the dosage suggested for clinical use in man

SUMMARY

Subacute toxicity of a new cholecystographic contrast medium B 8890 was investigated Daily doses of 500 mg/kg in the rat and 200 mg/kg in the dog were tolerated while larger doses 1 000 mg/kg and 800 mg/kg body weight respectively caused some side effects and changes in laboratory data The new compound is less nephrotoxic than iopanoic acid in the rabbit

ZUSAMMENFASSUNG

Die subakute Toxizitat eines neuen Gallenkontrastmittels B 8890 wurde untersucht Tagliche Dosen von 500 mg/kg in der Ratte und 200 mg/kg im Hund wurden vertragen wahrend hohere Dosen 1 000 mg/kg bzw 800 mg/kg Korpergewicht Nebeneffekte verursachten und die Laborwerte veranderten Die neue Substanz ist beim Kaninchen weniger nephrotoxisch als Iopansaure

RÉSUMÉ

Les auteurs ont etudie la toxicite subaigue d un nouvel agent cholecystographique B 8890 Des doses quotidiennes de 500 mg/kg chez le rat et de 200 mg/kg chez le chien ont ete tolerees alors que des doses plus importantes de 1 000 mg/kg et de 800 mg/kg de poids corporel respectivement ont donne lieu a quelques effets secondaires et a des modifications des resultats biologiques Ce nouveau compose est moins nephrotoxique chez le lapin que l acide iopanoique

Table 3

Action on renal function. PAH and creatinine clearances (ml/min ±SE) of the left kidney (treated) in comparison with the right (control)

Concentration (%)	B 8890				Iopanoic acid			
	PAH		Creatinine		PAH		Creatinine	
	Right	Left	Right	Left	Right	Left	Right	Left
1	7.6 ± 1.11	6.9 ± 1.51	2.77 ± 0.43	2.02 ± 0.60	10.0 ± 2.13	0.21 ± 0.066	3.41 ± 0.47	0.05 ± 0.022
0.5	8.5 ± 1.64	6.8 ± 1.64	2.45 ± 0.43	1.70 ± 0.41	8.7 ± 1.06	2.31 ± 1.24	2.85 ± 0.28	0.67 ± 0.34
0.25	8.2 ± 0.75	8.9 ± 1.77	2.90 ± 0.28	2.5[illegible] ± 0.32	11.2 ± 2.08	3.1[illegible] ± 0.98	3.35 ± 0.57	0.60 ± 0.16

Dosages of 500 mg/kg daily in rats, and of 200 mg/kg daily in dogs (being 10 and 4 times greater, respectively, than the proposed human dosage), administered for 20 days over 4 weeks, were readily tolerated. Higher doses (1 000 mg/kg daily in rats, and 800 mg/kg daily in dogs) produced some side effects and some changes in the laboratory findings. In rats of either sex the total blood bilirubin proved higher than in the untreated controls. The information available in the literature (MAGGIORE et coll. 1963) suggests however that this may simply reflect competition between the contrast medium and the biliary pigment for common excretion mechanisms, as opposed to true toxicity. The administration produced an increase in liver weight both in rats and in dogs; this was associated with swelling of the liver cells, which exhibited an acidophilic cytoplasm reflecting a reduction in basophilic bodies. The fact that serum transaminase levels and the rate of BSP excretion remained normal indicated that liver cell damage was negligible.

The other organ that commands attention in the investigation of the toxicity of an oral contrast medium for cholecystography is the kidney, which may eliminate a considerable quantity of the product owing to rapid and complete intestinal absorption or to existing liver deficiency. Numerous observations of severe renal impairment following cholecystography are also reported in the literature (FINK & TEILLICK 1964).

B 8890 presented an extremely low measure of nephrotoxicity in both animal species subjected to moderate dosage. Even with the higher dosage levels there was only a limited increase in BUN and then only in male animals; such a finding might very well be due to causes other than renal impairment, considering that the urinalysis remained normal and the renal histology was practically

noncontributory The new compound, injected directly into the renal circulation in rabbits, proved much less nephrotoxic than iopanoic acid this being the oral contrast medium for cholecystography best established and extensively used

Rats treated with both dosage levels of B 8890 and dogs receiving 800 mg/kg of the product daily presented a significant increase in thyroid weight relative to untreated controls together with histologic evidence of functional hyper activity of the gland. On the other hand this phenomenon was not observed in dogs treated 20 times during a period of 4 weeks with doses four times the human dose At the dosage level of 800 mg/kg daily, B 8890 produced side effects involving the gastrointestinal tract of dogs frequent episodes of vomiting and diarrhea occurred and in the last week of treatment the animals consumed about half the food eaten by the untreated controls, and lost weight accordingly

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Subacute toxicity of a new cholecystographic contrast medium B 8890 was investigated. Daily doses of 500 mg/kg in the rat and 200 mg/kg in the dog were tolerated while larger doses 1 000 mg/kg and 800 mg/kg body weight respectively caused some side effects and changes in laboratory data The new compound is less nephrotoxic than iopanoic acid in the rabbit

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REFERENCES

BERGMEYER H U Fructose 1, 6 diphosphat aldolase A Colorimetrische Bestimmung mit 2 4 Dinitrophenylhydrazin *In* Methoden der enzymatischen Analyse, p 724 Verlag Chemie GmbH Weinheim/Bergstr 1962

— Glutamat Oxalacetat Transaminase Colorimetrische Bestimmung mit 2 4 Dinitrophenylhydrazin Ibid p 842

— Glutamat Pyruvat Transaminase Colorimetrische Messung mit 2 4 Dinitrophenylhydrazin Ibid p 851

BESSEY O A LOWRY O H and BROCK M J *A method for the rapid determination of* alkaline phosphatase with five cubic millimeter of serum J biol Chem 164 (1946) 321

BRATTON A C and MARSHALL E K A new coupling component for sulfanilamide determination J biol Chem 128 (1939), 537

FAWCETT J K and SCOTT J E A rapid and precise method for the determination of urea J clin Path 13 (1960) 156

FINK H L and FELPLICK J G Acute renal failure following oral cholecystography Radiology 83 (1964) 1100

HARTEL A HELGER R und LANG H Messung von sehr geringen o Toluidin Konzentrationen im Arbeitsplatz fur Blutzuckerbestimmung Z klin Chem klin Biochem 7 (1969) 14

IDBOHRN H and BERG N On the tolerance of the rabbit s kidney to contrast media in renal angiography Acta radiol 42 (1954) 121

JENDRASSIK L und GROF P Vereinfachte photometrische Methoden zur Bestimmung des Blutbilirubins Biochem Z 297 (1938) 81

LANGLEY W D and EVANS M The determination of creatinine with sodium 3 5 dinitro*benzoate J biol Chem 115 (1936) 333*

MAGGIORE Q CARTER M e BILLING B H Influenza di varie sostanze radioopache escrete con la bile sul trasporto epatico della bilirubina (In Italian) Rass Fisiopat sin ter 35 (1963) 500

ROSATI G DE MICHELI P and SCHIANTARELLI P Pharmacologic properties of a new oral contrast medium for cholecystography Acta radiol Diagnosis 12 (1972) 335

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A NEW CONTRAST MEDIUM FOR HYSTEROSALPINGO PELVIGRAPHY

by

L Bjork U Erikson B Ingelman and H Wilbrand

A relatively large quantity of contrast medium, as in hysterosalpingo-pelvigraphy entering the peritoneal cavity may produce adverse effects partly due to its hyperosmotic character and partly due to its chemical structure The relatively few investigations published regarding such effects seem to support this hypothesis

Kjellberg (1942) using a solution of Perabrodil noted a high incidence of pain in his patients following pelvigraphy and added a local anaesthetic to the contrast medium to overcome this symptom Jorulf & Wilbrand (1970) reported that a modern contrast medium, meglumine diatrizoate, in an aqueous solution containing 310 mg I/ml (Angiografin Schering), produced abdominal pain after hysterosalpingo-pelvigraphy in a quarter of their material. This appears to indicate that further improvements in the contrast media for hysterosalpingo-pelvigraphy are needed

A new contrast medium Ph DZ 59A (Fig 1) has been synthesized and aqueous solutions of its methylglucamine salt (Ph DZ 59B) have been clinically tested in various types of angiography and arthrography They proved to give

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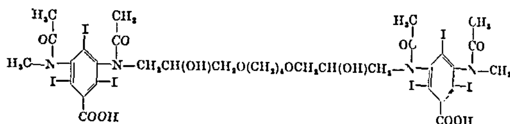


Fig 1 Chemical structure of the contrast medium in its acid form

fewer symptoms and to affect the circulation less than certain media currently used (BJORK et coll 1969 a, b, c, 1970, 1971 a) This contrast medium, partly due to differences in its physical and chemical properties and partly because of differences in the chemical structure of the molecule should theoretically cause less damage to vascular endothelium and to mucous membranes than other media currently used *Experimental and clinical investigations appear to support this premise* (BJORK et coll 1969 a, b, c, 1970, 1971 a, b, and unpublished results, LINDBLAD & FALK)

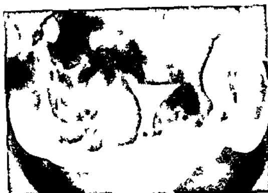
A trial of Ph DZ 59B in hysterosalpingo pelvigraphy forms the subject of this communication

Material This consisted of 56 consecutive patients all referred for hystero salpingo pelvigraphy as part of an examination for sterility but otherwise un selected Six were excluded because the peripheral parts of the fallopian tubes appeared to be obstructed The age of the patients varied between 16 and 37 years (mean 27 years)

Methods The patients were given 50 mg butylscopolamine bromide and 50 to 100 mg pethidine chloride one hour before the examination The contrast medium consisted of an aqueous solution containing 57 g Ph DZ 59B per 100 ml corresponding to 235 mg iodine per ml The examination technique was the same as described previously by JORULF & WILBRAND and consisted of the intermittent injection of the contrast medium under TV fluoroscopic control Full size films or 70 mm × 70 mm films from the image intensifier output screen were ob tained After the uterine cavity and the fallopian tubes had been filled with contrast medium (average 6 ml, range 3 to 12 ml) additional quantities were injected in order to outline the pelvic part of the peritoneal cavity the total amount used varied between 13 and 50 ml with a mean of 31 ml Changes in the peritoneal cavity around the fallopian tubes and the ovaries were demon strated with a vertical central roentgen beam with the patient prone and supine as well as with a vertical and horizontal central beam with the patient on her side



a



b

Fig 2 a) Normal hysterosalpingogram with Ph DZ 59B b) Additional amount of contrast medium injected for pelvigraphy

The patients were questioned about abdominal pain and nausea before and during the procedure immediately after it and at 2 6 and 24 hours They were asked to describe the abdominal pain as either slight, moderate or severe The *rectal temperature* was *taken before and after the examination the pulse rate* was also recorded

Results

The radiographic result of the examination was satisfactory in all the patients with good demonstration of the uterine cavity and fallopian tubes as well as of the pelvic part of the peritoneal cavity (Fig 2)

Significant changes in the rectal temperature or in pulse rate after the examination were not recorded in any patient Three patients had slight and two *moderate abdominal pain immediately after* the examination In three patients the pain had disappeared after two hours and in all patients after six hours Four patients reported nausea immediately after the examination and one of them vomited The nausea lasted six hours in two of these whereas in the other two

patients it had disappeared after two hours. One of the patients with nausea also had slight abdominal pain. Two of the five patients with abdominal pain following the examination had normal roentgenologic findings. In the three others and in those with nausea, varying degrees of abnormality, such as sactosalpinx or peritoneal adhesions in the pelvic region, were present.

Discussion

Only five (10 per cent) of the patients of the present material complained of slight or moderate abdominal pain, usually of short duration, following the hysterosalpingo pelvigraphy against the 25 per cent of those of JORULF & WILBRAND similarly or more severely affected by methylglucamine diatrizoate with an iodine content of 310 mg/ml. The iodine concentration of the contrast medium Ph DZ 59B employed in the present investigation was 235 mg iodine per ml. Both contrast media were used as their methylglucamine salts. The iodine concentrations of the solutions were however different so that a strict comparison between Ph DZ 59B and methylglucamine diatrizoate cannot be made. The lower frequency of abdominal pain with Ph DZ 59B than with the diatrizoate preparation may be due to several contributing factors. As already stated Ph DZ 59B was used at a lower concentration than the other preparation and its chemical structure and molecular size confer advantageous physical, chemical and biologic properties.

The obvious impossibility of conducting comparative examinations of two contrast media in hysterosalpingo pelvigraphy in the same patient makes comparison difficult. Differences in consecutive groups of patients and the examination technique may exist. All examinations in both groups were however performed by two radiologists. One of them took part both in the present and the earlier but similar investigations (JORULF & WILBRAND). There were no obvious differences in the examination technique or in the amount of contrast medium used. The indications for the examination, the age of the patients and the number of abnormal findings were similar in both groups.

Whether the nausea experienced by four patients was caused by the contrast medium or by mechanical factors produced by the hysterosalpingographic procedure is unknown since all four patients had a sactosalpinx that was distended during the examination.

Ph DZ 59B gave excellent radiographic results in hysterosalpingo-pelvigraphy. The iodine concentration (235 mg/ml) was adequate and a more concentrated solution appeared unnecessary, the compound was well tolerated. The subjective adverse effects were fewer than in a similar group in which methylglucamine diatrizoate (Angiografin) was used. Strict comparison between the two groups is

impossible but it would appear that Ph DZ 59B is a valuable contrast medium in hysterosalpingo-pelvigraphy

The solution used in this investigation contained 235 mg iodine per ml and had a relatively low viscosity of about 5 cP at 37° C This low viscosity is ideal when pelvigraphy is included in the examination although for examinations of the mucosa of the uterus and fallopian tubes a higher viscosity and a lower iodine content may be desirable (UNNERUS 1967) A higher viscosity may be achieved by adding an inert polymer as for example a dextran fraction to solutions of contrast media (BACKMAN et coll 1952 BERGMAN et coll 1956 UNNERUS) Preliminary investigations have also indicated that it is possible to prepare solutions of Ph DZ 59B of high viscosity also by the addition of suitable dextran fractions to the solutions

SUMMARY

A new contrast medium Ph DZ 59B has been tried in hysterosalpingo-pelvigraphy with good radiographic results It was well tolerated with only few and slight adverse effects of short duration

ZUSAMMENFASSUNG

Ein neues Kontrastmittel Ph DZ 59B ist bei Hysterosalpingo Pelvigraphien mit guten radiographischen Ergebnissen erprobt worden Es wurde gut vertragen mit nur wenigen und leichten Nebenwirkungen von kurzer Dauer

RÉSUMÉ

Un nouveau moyen de contraste Ph DZ 59B a été essayé en hysterosalpingo-pelvigraphie avec de bons résultats radiographiques Il a été bien toléré avec seulement quelques effets secondaires légers de courte durée

REFERENCES

BACKMAN S V EMBRING G and INGELMAN B Komposition for rontgendiagnostik (In Swedish) Swedish patent 174 789 1952

BERGMAN F NORMAN O and SJOSTEDT S Perjodal H viscous a water soluble contrast medium containing dextran Acta radiol 46 (1956) 587

BJORK L ERIKSON U and INGELMAN B (a) Clinical experiences with a new type of contrast medium in peripheral arteriography Amer J Roentgenol 106 (1969) 418

— — — (b) Clinical experience with a new type of contrast medium in carotid arteriography Amer J Roentgenol 107 (1969) 637

— — — (c) Clinical experience with a new type of contrast medium in angiocardiography and thoracic aortography Amer J Roentgenol 107 (1969) 848

— — — A new type of contrast medium in arthrography. Amer. J. Roentgenol. 109 (1970), 606.

— — — (a) *Clinical experience with a new type of contrast medium in selective coronary arteriography.* Fortschr. Röntgenstr. 114 (1971), 816.

— — FALK, J., INGELMAN, B., LINDBLAD, G. och STENPORT, G. (b) Erfarenheter av ett nytt injicerbart kontrastmedel. (In Swedish.) Nord. Med. 85 (1971), 631.

JORULF, H. und WILBRAND, H. F.: Erfahrungen mit Kontrastmittelnebenwirkungen bei Hysterosalpingo-Pelvigraphien. Fortschr. Röntgenstr. 113 (1970), 510.

KJELLBERG, S. R.: Hysterosalpingopelvigraphie. Acta radiol. (1942) Suppl. No. 43.

LINDBLAD, G. and FALK, J.: Personal communication.

UNNERUS, C. E.: Perjodal Viskos — ett nytt kontrastmedel vid salpingografi. (In Swedish.) Nord. Med. 77 (1967), 48.